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Thermal Infrared Spectra of Natural and Manmade Materials: Implications for Remote Sensing

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This report is a compilation of laboratory thermal infrared reflectance spectra recorded over various spectral ranges between 4000 and 400 cm^{-1} (2.5 - 25.0 micrometers) for natural and manmade materials of potential interest to both military and civilian sectors. Knowledge of the position and shape of significant spectral features as detected by remote spectrometers or spectral radiometers is necessary to discriminate between targets on the basis of either spectral emittance or reflectance. Many of the samples in this study display spectral features in either, or both of the 3- to 5- micrometer or the 8- to 14- micrometer regions of the spectrum in which terrestrial remote sensing is possible. Such information can be used to devise image enhancement strategies for data in hand or to design new instruments or experiments utilizing thermal multispectral data.

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PREFACE

This work was done under DA Project, 4A161102B52C, Task A, Work Unit 010, "Hyperspectral Research."

The work was performed during the period January 1985 to March 1989 under the supervision of Dr. J.N. Rinker, Chief, Remote Sensing Division; and Mr. John Hansen, Director, Research Institute.

Colonel David F. Maune, EN, was Commander and Director, and Mr. Walter E. Boge was Technical Director of the Engineer Topographic Laboratories during preparation of the report.

THERMAL INFRARED SPECTRA OF NATURAL AND MANMADE MATERIALS: IMPLICATIONS FOR REMOTE SENSING

INTRODUCTION

Scope. The wavelengths at which materials interact with electromagnetic radiation depend on their composition. At wavelengths greater than 2.5 micrometers, molecules begin to exhibit strong, fundamental vibration bands. In this spectral region, compositional information about materials results from excitation of internal vibrations of constituent atoms relative to each other or of atomic groups relative to the overall molecular structure. Molecular vibrations are commonly classified as bond-stretching or bond-angle bending, and evidence for fundamentals, overtones, and combination tones may occur in this region. Solar radiance at wavelengths greater than 2.5 micrometers is so low that the radiance received from a room temperature surface is dominated by thermal emittance. Thus, the region of the spectrum beyond 2.5 micrometers is often referred to as the thermal infrared.

Background. Chemists have for many years used thermal infrared spectra for compositional and structural analysis of both organic and inorganic materials; the region between 2 and 16 micrometers is often termed the "fingerprint region." Such studies are based on transmittance measurements, which involve passing radiation through a sample and measuring the transmitted radiation as a function of wavelength. The variations of transmittance of a material with wavelength are solely a function of its absorption coefficient. This simple relationship between absorption coefficient and spectral features makes such spectra relatively easy to interpret. Libraries and data bases of thermal infrared transmittance spectra of many materials are available (Ferraro, J.R., ed., 1982; Pouchert, Charles J., 1985).

However, thermal infrared remote sensors detect emittance or reflectance rather than transmittance. Emittance and reflectance are complex processes that depend not only upon the absorption coefficient of materials but also on their refractive index, physical state, and temperature. Remote sensing data are further affected, often dramatically, by a variety of factors, e.g. weathering, vegetation, desert varnish, high surface salinity, etc. Details of the interaction of infrared radiation with various surfaces have been treated elsewhere (Eastes, J.W., 1989; Salisbury, J.W., and Eastes, J.W., 1985; Salisbury, J.W., Hapke, B., and Eastes, J.W., 1987; Hunt, G.R., and Vincent, R.K., 1968). The significant point is that reflectance measurements are more pertinent to remote sensing applications than transmittance spectra. The purpose of this report is to provide spectral reflectance data on a wide variety of potential target materials, which may be used to aid the interpretation of multispectral thermal infrared imagery. Further editions of this data base are expected to be produced as additional spectral measurements are made.

Using Thermal Infrared in Remote Sensing. For the past several years, two types of thermal infrared spectral data have been used that show promise for terrain compositional analysis via remote sensing (Kahle, A.B. and Goetz, A.F.H., 1983; Kahle, A.B., Shumate, M.S., and Nash, D.B., 1984). Active systems that measure spectral reflectance directly are based on tunable carbon dioxide lasers working in the wavelength range of 9.1 to 11.2 micrometers. Material classification based on reflectance characteristics offers several advantages. Active systems do not have to distinguish between temperature changes and emissivity differences. They can have higher spectral resolution and are more able to handle low spectral variations. Passive systems that measure thermal emittance lack spectral sensitivity when the reflectance is low and the emissivity is near unity. Furthermore, they are extremely sensitive to temperature. Because passive systems operating in the thermal infrared must detect quite low signal

levels in comparison with those systems operating at shorter wavelengths, wide aperture optics are used to obtain adequate SNR at the high resolution necessary to detect many of the narrow spectral features reported in the published literature. Thus, higher resolution than has been used in passive imaging systems may be necessary for many applications. However, the advantages for active systems must be weighed against the greater simplicity and more established technology of passive systems. Active systems are not currently available at the same level of development as passive ones.

EXPERIMENTAL

Spectral Measurements. Spectral emittance of materials is best measured directly, preferably under similar physical conditions as those under which remote sensing observations are to be made. However spectral emittance measurements are difficult to make because of the limited energy available at realistic sample temperatures, the difficulty of controlling or even knowing the sample temperature, and the likelihood of stray emission and absorption within the spectrophotometer, which can become very important when observing room temperature samples. Consequently, reflectance measurements are usually used to predict emittance based on Kirchhoff's relation, $E = 1 - R$. Here, E and R are total emittance and reflectance. Remote sensors, however, detect only emittance in their direction. This value is best estimated in the laboratory by measuring directional hemispherical reflectance (Nicodemus, F.E., 1965). If a sample is illuminated from the direction of an observer and the resulting reflectance over two pi steradians is measured, the fraction of photons absorbed by the target can be determined. By using another form of Kirchoff's law, $E = A$, where A is absorptance, emittance can be predicted.

The most practical way to measure directional hemispherical reflectance is with a spectrophotometer equipped with an integrating sphere. Access to such an instrument has recently become available to the U.S. Army Engineer Topographic Laboratories (ETL) and many spectra presented in this report have been recorded with this equipment. However, much of the data has been acquired over several years using a spectrophotometer equipped with a bi-directional reflectance accessory. Measurements with this attachment can be made at either a specular or off-specular angle. Data obtained in this way display spectral features correctly on a wavelength basis, but cannot be interpreted in terms of directional emittance, i.e. Kirchhoff's relation does not hold for measurements of surfaces having a high specular reflectance component, such as do many manmade materials. Hunt and Vincent (1968) have shown, however, that the $E = 1 - R$ relation does hold to a first-order approximation for particulate surfaces under terrestrial conditions; therefore, spectra of particulate geologic samples measured with this technique are reasonably good qualitative indicators of their emittance behavior.

Spectrophotometers. Directional hemispherical reflectance spectra were recorded with a Nicolet 5DXB Fourier transform infrared spectrophotometer located at the US Geological Survey, Reston, VA. This instrument, which has 4-cm $^{(-1)}$ spectral resolution between 2.5 and 13.5 micrometers, has an external port to which a gold-coated integrating sphere is attached. The sphere is 12.7 cm in diameter, and a 2.5-cm illumination port is in the top of the sphere at 10 degrees off the vertical, through which a beam passes to fall on a 2.5-cm sample/reference port in the bottom of the sphere. A 2.5-cm detector port is in the side of the sphere to which is attached a liquid nitrogen-cooled, mercury-cadmium-telluride (MCT) detector. Sphere performance was calibrated against known reflectances of halon, a diffuse gold surface, a front-surfaced aluminum mirror, water, and a black-body cone. The reference used was a diffuse gold surface.

Bidirectional reflectance measurements were made with a Perkin-Elmer Model 983 spectrophotometer, which is a ratio recording dispersive instrument. Spectra were recorded using a

bidirectional reflectance accessory mounted in the sample compartment. The accessory can be operated in two optical geometries. One is a specular geometry with the sample plane normal to the plane formed by the incident and reflected beams. The other is an off-specular geometry achieved by rotating the sample plane 30° off the normal to the plane formed by the incident and reflected beams. The attachment uses two 90° field-of-view off-axis, ellipsoidal mirrors with a center-to-center phase angle of 83°.

The established specular reflectance standard in the mid-infrared is a gold-coated mirror; however, no established diffuse reflectance standard has been adopted. A diffuse gold surface is often used as well as particulate alkali halides, such as KBr, KCl, or NaCL. As the spectra presented here were recorded over a period of several years, several such references have been used.

Sample Acquisition and Preparation. Samples were collected during various field studies, were purchased commercially, or donated by individuals.

Cup-shaped sample holders 3-mm deep were used for measurements of particulate samples, e.g., soils and powdered minerals. Because the measurement area illuminated by the beam of the Model 983 spectrophotometer was small (2x2 mm), particulate samples measured with this instrument were repeatedly poured into a sample holder and measured, and the results were averaged to obtain data on a random orientation of grains. Solid samples, e.g. rock specimens, were measured repeatedly at slightly different positions in order to obtain representative spectra. The optics of the Model 5DXB spectrophotometer provide a larger infrared beam (1.54 cm diameter); thus, repetitive measurements are not necessary to obtain representative spectra with this system.

DISCUSSION OF SPECTRA

The thermal infrared part of the spectrum is often referred to by its frequency rather than by its wavelength. Wavelength is expressed in micrometers or nanometers. Frequency is expressed, not in cycles per second, but in wavenumbers, $cm^{(-1)}$ often called reciprocal centimeters. The wavenumber is simply the number ot waves per centimeter, and is equal to the reciprocal of the wavelength in centimeters. To convert from frequency in wavenumbers to wavelength in micrometers, one may use the following formula:

$$\text{Wavelength (micrometers)} = 10{,}000/\text{wavenumber (cm-1)}$$

The appearance of the infrared spectrum of a given solid material is governed by several parameters. They include the experimental mode used to record the spectrum (reflection, emission), as well as the sample condition (smooth or rough plane surface, particulate, etc.). Because varying these parameters will alter the appearance of a spectrum, comparing spectral information requires that the data be collected using the same experimental conditions or that the effects of varying any of the parameters be fully understood and accounted for.

Specular vs. Diffuse Reflectance. Spectra are discussed in terms of two types of reflectance, which must be understood for valid spectral interpretations. Reflectance of surfaces that are smooth, relative to the wavelength of incident radiation, is almost entirely composed of specular or mirrorlike reflectance. At wavelengths where the absorption coefficient is very high, as near the fundamental vibration bands of strongly absorbing minerals, the measured reflectance will be predominantly specular. Such samples display so-called reststrahlen maxima associated with their fundamentals.

The reflectance of rough or particulate surfaces contains both specular and other contributions. For particulate samples with grains smaller than the incident radiation beam but larger than the wavelength, the total reflectance from a non-absorbing material is the result of specular reflectance from the faces of randomly oriented particles, of refraction through them, and of a small amount of diffraction at the edges. This combination of specular reflection, refraction, and diffraction is commonly known as diffuse reflectance. A distinction is made between diffusely reflected radiation that has not passed through a sample particle, and diffusely reflected radiation that has entered one or more particles and has been partially absorbed before being returned to the observer. In this latter case, more radiation is absorbed in the vicinity of a molecular vibration band, where the absorption coefficient is high, than in adjacent spectral regions of low absorption. The reflectance spectrum then displays molecular vibration bands as reflectance minima rather than maxima.

Because the absorption coefficients of different molecular vibration bands vary widely, a material may exhibit reflectance maxima or reflectance troughs, i.e., minima. Reflectance maxima occur at strong bands where specular reflectance dominates and reflectance minima occur at weaker bands where diffuse reflectance dominates. The weakest inorganic vibrational bands typically occur at wavelengths shorter than 5 micrometers and are usually expressed as reflectance troughs. Molecular vibration bands of organic materials are often an order of magnitude weaker than those of inorganic substances, with the result that spectral features of organic samples are almost always expressed as reflectance troughs, or minima, rather than as peaks.

Origins of Spectral Features. The strongest features in the spectra of silicate materials occur between 1176 and 833 cm$^{(-1)}$ (8.5 and 12.0 micrometers). Features in this range are the result of selective absorption at wavelengths corresponding to stretching vibrations of Si-O bonds. The most intense feature in this region is a doublet centered at 8.6 micrometers due to quartz. As minerals change from felsic to ultramafic, a progressive shift of features to longer wavelengths is observed. Because these intense, well-defined features fall in the 8 to 14 micrometer atmospheric window, they have been most useful for terrestrial remote sensing (Kahle, A.B., and Goetz, A.F.H., 1983).

Bands between 833 and 666 cm$^{(-1)}$ (12 and 15 micrometers) generally indicate that the silicate structure contains three-dimensional lattices in which (Si,Al)-O-(Si,Al) bridges have formed. The features in this region are due to Si-O-Si and Si-O-Al symmetric stretching motions, during which it is the silicon or aluminum, rather than the oxygen atoms that are most displaced from their equilibrium positions. For example, in quartz, three quite sharp and intense features appear owing to symmetric Si-O-Si structures. These occur in the form of a doublet near 799 cm$^{(-1)}$ (12.5 micrometers) and a third band near 700 cm$^{(-1)}$ (14.3 micrometers).

The carbonate ion yields a relatively intense, well-defined feature near 1400 cm$^{(-1)}$ (7 micrometers), owing to asymmetric C-O stretching vibrations and weaker bands near 875 and 700 cm$^{(-1)}$ (11.4 and 14.3 micrometers) because of bending modes. Carbonate bands are common in sedimentary rocks, and also appear in igneous rocks owing to small amounts of calcite that are often present as a result of alteration of plagioclase. Many soils also contain considerable carbonaceous material.

The sulfate ion displays a fundamental feature near 1150 cm$^{(-1)}$ (8.7 micrometers) and bending modes near 600 cm$^{(-1)}$ (16.7 micrometers). In addition, two groups of narrow, closely spaced bands appear centered around 1650 cm$^{(-1)}$ (6.1 micrometers) and 2175 cm$^{(-1)}$ (4.6 micrometers). Features due to sulfate are prominent in gypsiferous soils.

Other common inorganic spectral features are due to water and hydroxyl ion. Water and hydroxyl bands are usually prominent in rocks and soils, even when hydrated or hydroxylated minerals are nominally absent, because of the ubiquity of water in the terrestrial environment. Strong bands associated with OH stretching vibrations of water and hydroxyl groups occur between 3200 and 3700 $cm^{(-1)}$ (3.1 and 2.7 micrometers). The hydroxyl group is characterized by a strong sharp band in the region 3650 to 3700 $cm^{(-1)}$ (2.74-2.70 micrometers). Water of hydration usually exhibits one strong sharp band near 3600 $cm^{(-1)}$ (2.8 micrometers), and one or more strong sharp bands near 3400 $cm^{(-1)}$ (2.9 micrometers). Water of hydration is easily distinguished from hydroxyl groups by the presence of the H-O-H bending motion, which produces a medium band in the region 1600-1650 $cm^{(-1)}$ (6.2-6.1 micrometers). Free water has a strong broad band centered in the region 3200 to 2400 $cm^{(-1)}$ (3.1-4.2 micrometers); the H-O-H bending motion generally occurs near 1650 $cm^{(-1)}$ (6.1 micrometers).

Many natural, e.g. vegetation, as well as manmade materials, such as paints, plastics, fabrics, petroleum derivatives, etc., are composed of organic components displaying distinct spectral features. Vegetation spectra as well as those of cotton-based materials, e.g. cotton fabrics and certain camouflage materials, often closely resemble that of cellulose, the chief component of wood and plant fibers. Paints tend to display organic spectral features owing to the extenders incorporated into their composition.

Bands in the spectra of organic materials may exhibit absorptivities an order of magnitude less than those of fundamental bands of inorganic mineral compounds. As a result, organic spectral features typically result from diffusely scattered radiation and are generally expressed as reflectance troughs, or minima, rather than reflectance peaks.

Bands arising from vibrations of carbon-hydrogen and carbon-carbon bonds constantly appear in the spectra of organic materials, because along with their various functional groups, organic compounds of all kinds contain carbon and hydrogen. Bands due to C-C stretching may appear at about 1500 and 1600 $cm^{(-1)}$ (6.7 and 6.2 micrometers) for aromatic bonds, at 1650 $cm^{(-1)}$ (6.1 micrometers) for double bonds, and 2100 $cm^{(-1)}$ (4.8 micrometers) for triple bonds. These bands, however, are often unreliable. More generally useful bands are due to the various carbon-hydrogen vibrations.

Absorption due to carbon-hydrogen stretching occurs at the high-frequency (low wavelength) end of the spectrum, between 2800 and 3300 $cm^{(-1)}$ (3.0 -3.6 micrometer's). Absorption due to various kinds of carbon-hydrogen bending, which occurs at lower frequencies (higher wavelengths) can also be characteristic of structure. Methyl and methylene groups absorb at about 1430 to 1470 $cm^{(-1)}$ (6.8 micrometers); for methyl, there is another band, quite characteristic, at 1375 $cm^{(-1)}$ (7.3 micrometers).

Compounds containing oxygen can give rise to features due to both hydrogen-oxygen stretching and carbon-oxygen stretching. In the spectra of compounds containing the OH group, e.g. cellulose, the most conspicuous feature is a strong broad band in the 3200 to 3600 $cm^{(-1)}$ (3.1-2.8 micrometers) region due to O-H stretching. Another strong, broad band, due to C-O stretching, appears in the 1000 to 1200 $cm^{(-1)}$ (10.0-8.33 micrometers) region, the exact location depending on the nature of the material.

The carbonyl group, C=O, frequently occurs in compounds used in paints and fabric dyes. The C=O stretching occurs in the neighborhood of 1700 $cm^{(-1)}$ (5.9 micrometers), but the exact wavelength depends on the family of compounds to which the material belongs.

Substances containing the nitrile group, C ≡ N, are often used in the manufacture of synthetic rubber, plastics, and synthetic fibers. A relatively strong nitrile feature occurs in the general region of 2300 to 2000 $cm^{(-1)}$ (4.3-5.0 micrometers).

The spectrum of cotton fiber (see Figure 1) illustrates a number of features commonly observed in organic materials. The spectrum is made up almost entirely of features expressed as reflectance minima. This is seen in the broad deep O-H stretching vibration band between 3200 and 3600 $cm^{(-1)}$ (3.1 and 2.8 micrometers) and a strong C-H stretching feature near 2900 $cm^{(-1)}$ (3.4 micrometers). The reflectance minima between about 1550 and 1000 $cm^{(-1)}$ (6.5 and 10 micrometers) are a series of strong, overlapping absorption bands due primarily to C-H and O-H bending and C-O-C stretching vibrations. The band near 890 $cm^{(-1)}$ (11.2 micrometers) is unassigned but is probably related to skeletal vibrations involving C-O stretching.

COMPOSITIONAL ANALYSIS USING SPECTRAL DATA

Remote sensing involves the use of spectral data to predict the composition and/or physical characteristics of distant targets. Spectra of specially prepared laboratory materials often display well-defined and resolved features that are relatively easy to interpret. Natural or field samples, e.g. rocks, soils, vegetation, however, normally yield more complex spectra. In these cases, spectral features may be poorly resolved, distorted, or masked. Spectral contributions from surficial components unrelated to the bulk composition of a substrate may dominate a spectrum, thus making spectra/composition correlations difficult and confusing. However, with the aid of laboratory spectral data from known samples, reasonable predictions about the nature of natural materials can often be made. The following section discusses spectra/composition correlations for three arid region soil samples that have been characterized by x-ray diffraction and other analyses, and it illustrates the use of spectral reference data to aid spectral interpretation of field samples. Also shown are examples of spectra in which features are associated with surficial species rather than bulk composition of the sample. Such spectra may also be useful in actual remote sensing situations, e.g. mapping the extent of contaminated areas such as in large oil spills.

Spectra for the three soils are shown in Figures 2, 3, and 4. Deep water absorption bands at 2.9 micrometers and sharper hydroxyl bands at 2.7 micrometers in the montmorillonite clay reference spectrum (see Figure 5), together with similar bands for each of the three soils, strongly suggest the presence of clay minerals in the latter. Soils 89-37 and 89-38 (Figures 2 and 3) contain substantial amounts of calcite (20% and 34%, respectively). Spectral evidence for this mineral in these soils appears as a deep absorption feature near 4.0 micrometers and a reflectance peak near 6.4 micrometers (compare with calcite reference spectrum in Figure 6). Soil 89-38 contains 13 percent thenardite (sodium sulfate). In this sample, thenardite is suggested by a reflectance trough in the spectrum near 4.7 micrometers, which corresponds to a similar feature in the reference spectrum of sodium sulfate at the same wavelength (see Figure 7). Sulfate surface reflectance associated with S-O stretching normally appears near 8.4 micrometers, but in this sample is only partially resolved from a silicate maximum appearing near 8.7 micrometers.

Silicate surface reflectance features occur between 8.5 and 12.0 micrometers. Quartz yields a strong surface scattering doublet centered at 8.6 micrometers accompanied by a weaker doublet

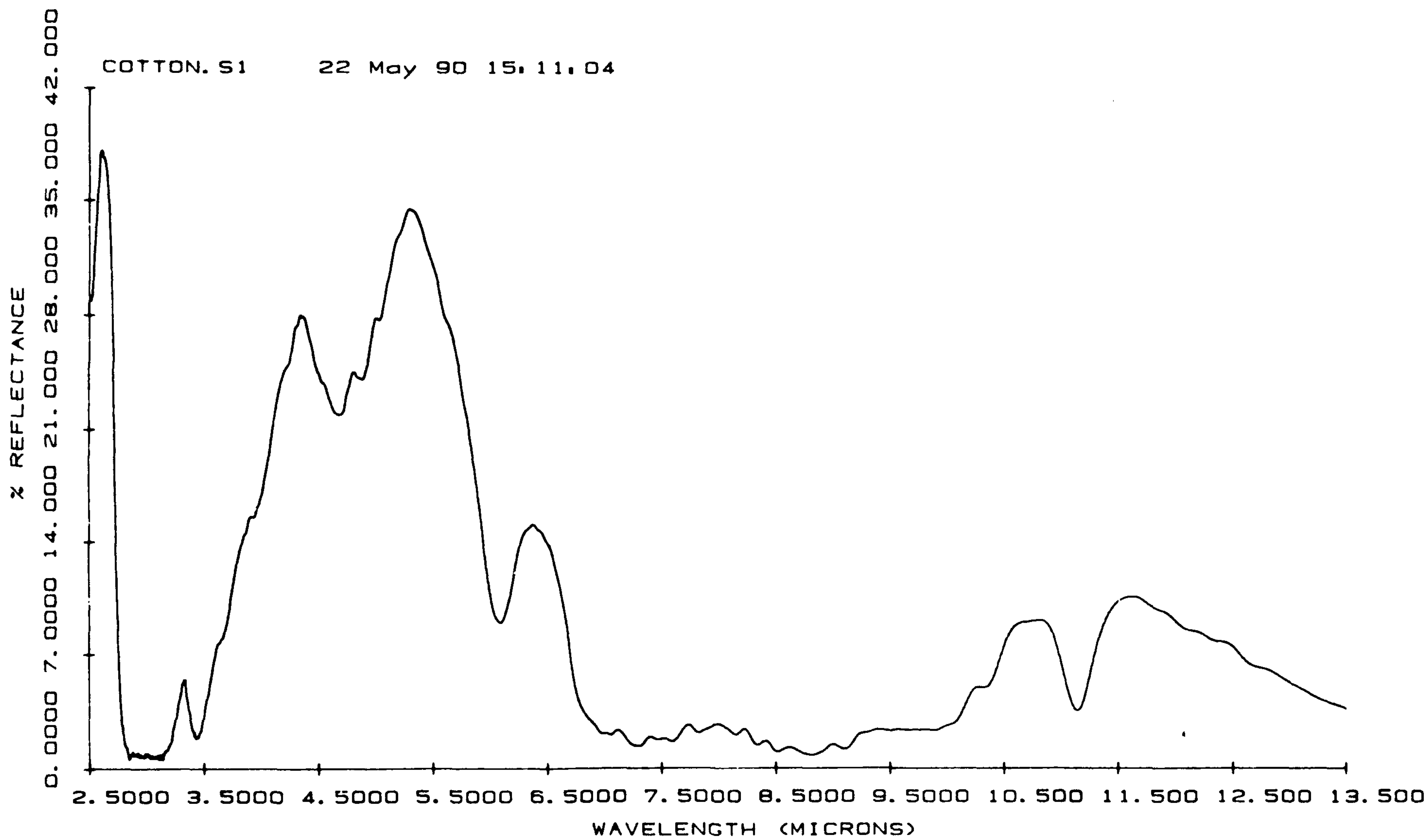

Figure 1. Reflectance of cotton fiber.

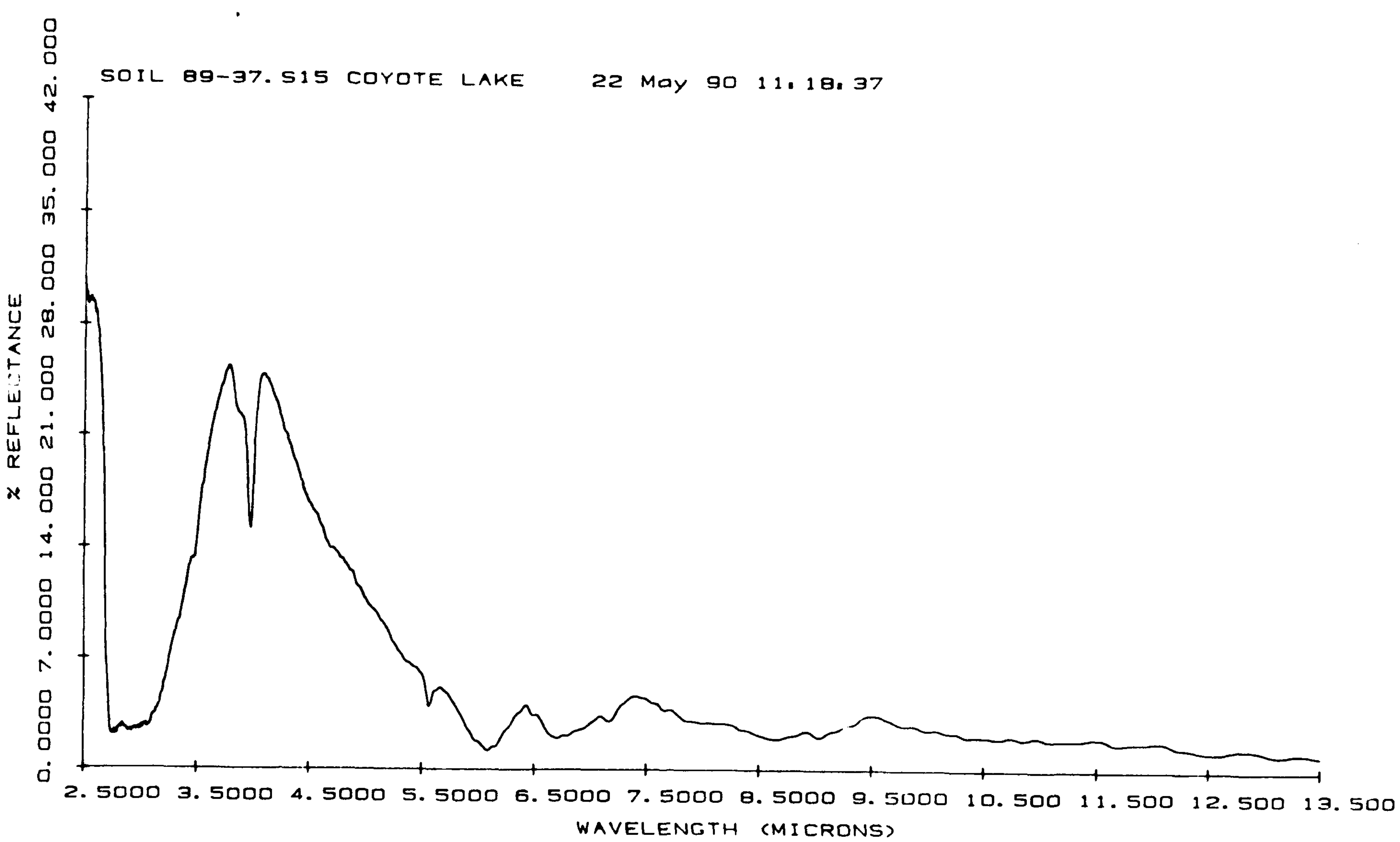

Figure 2. Reflectance of fine-grained playa soil.

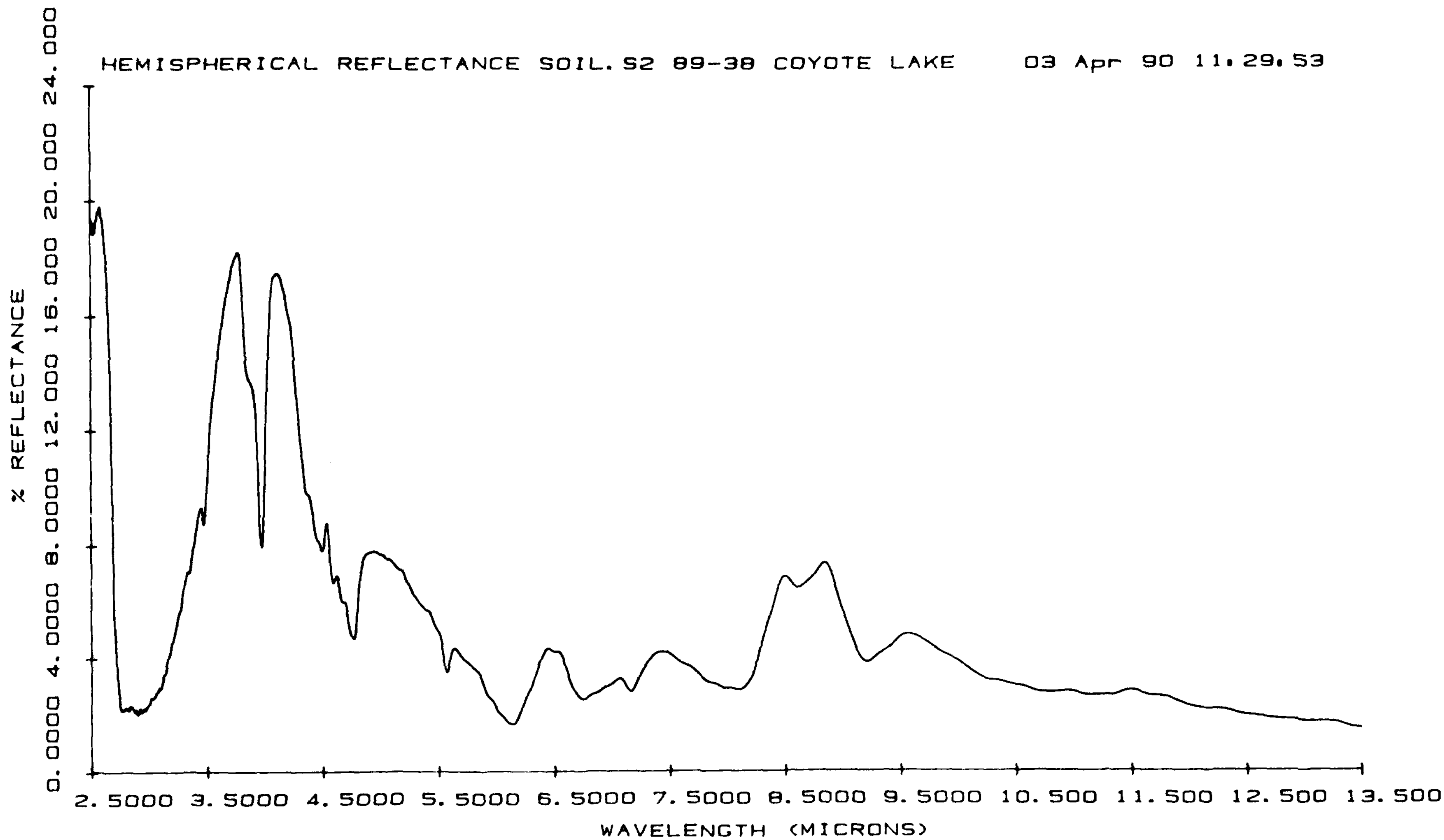

Figure 3. Reflectance of fine grained playa soil.

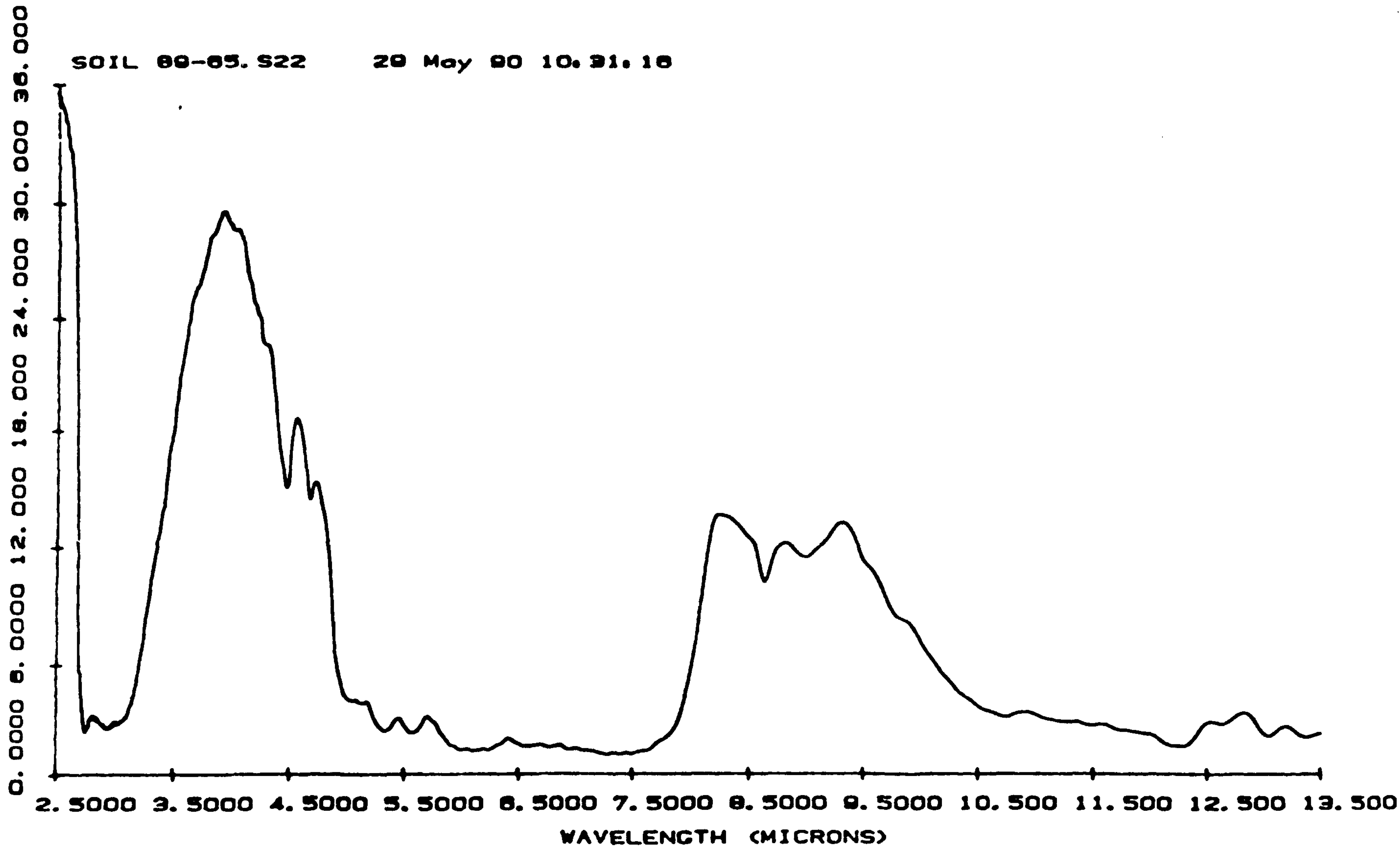

Figure 4. Reflectance of medium-grained playa soil.

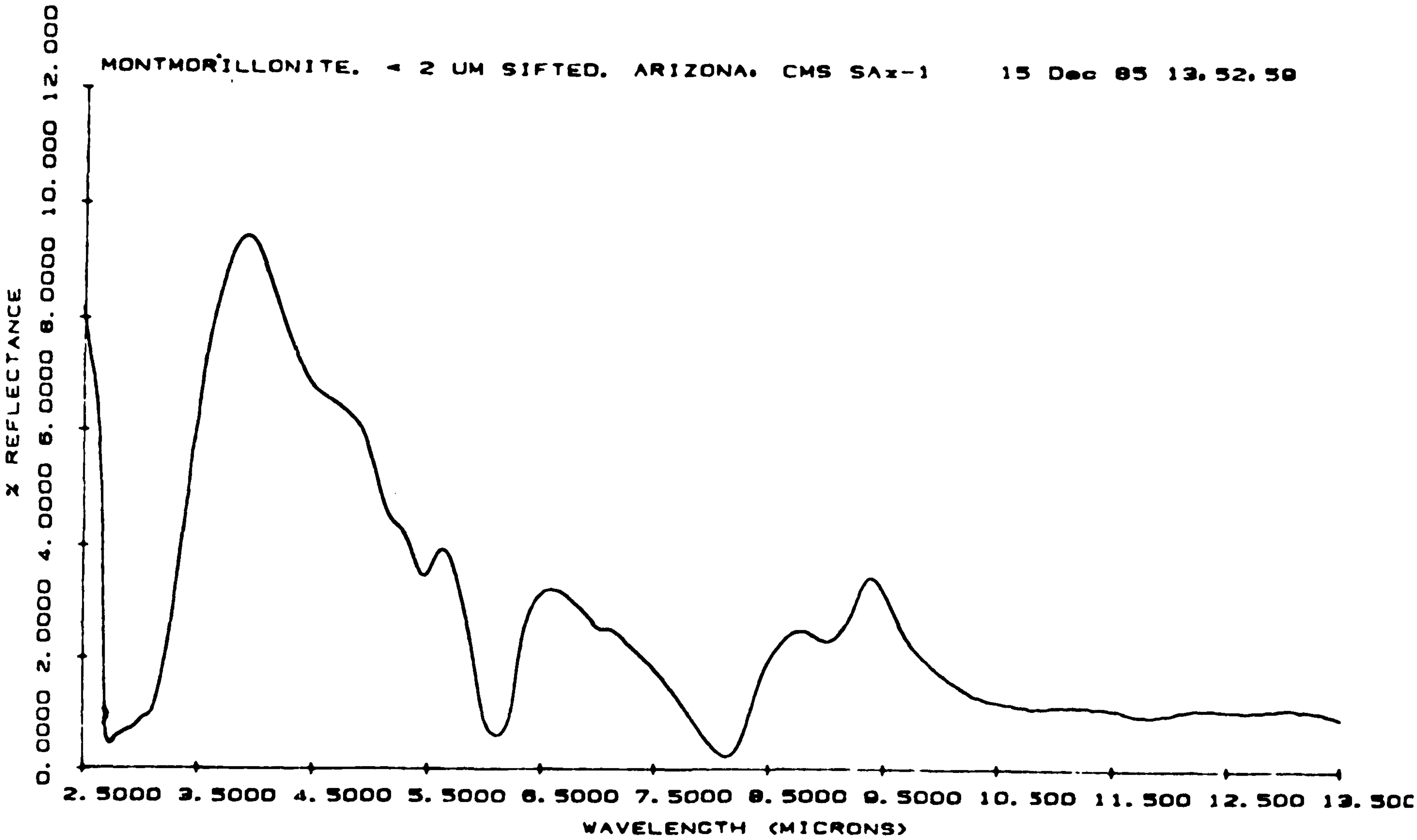

Figure 5. Reflectance of montmorillonite clay.

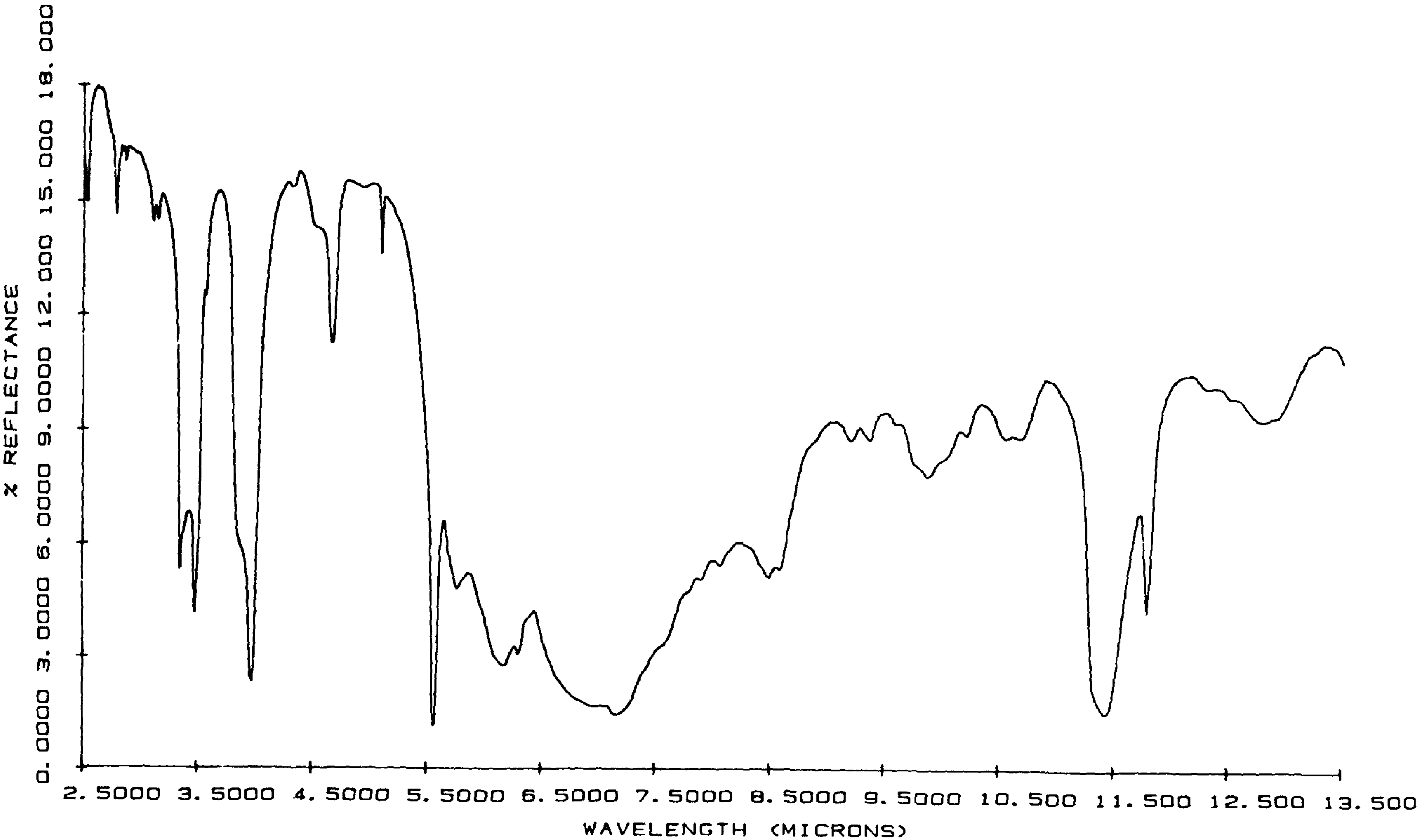

Figure 6. Reflectance of calcite.

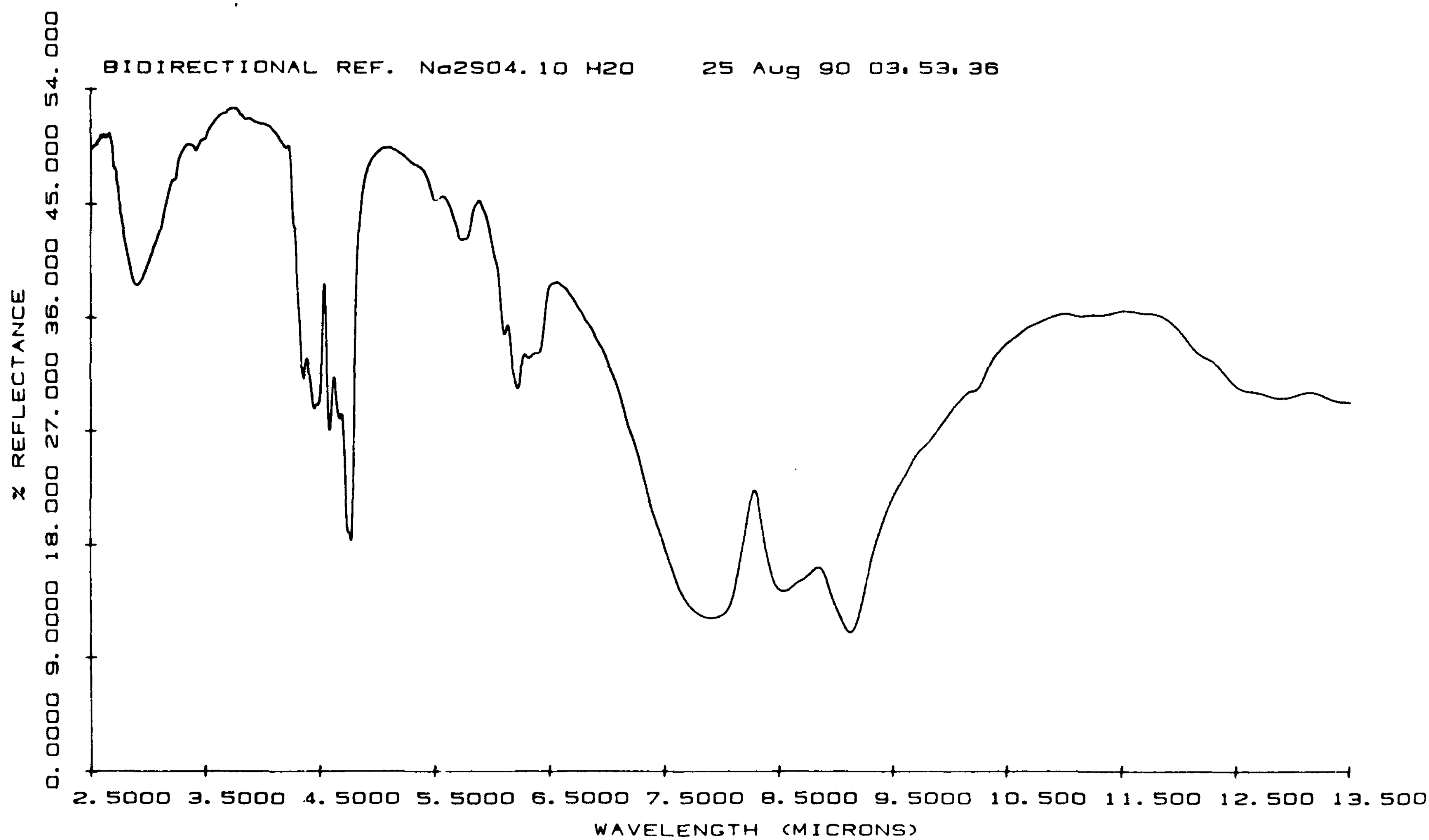

Figure 7. Reflectance of sodium solfate.

at 12.6 micrometers (see Figure 8). Clay minerals often display spectral maxima near 9.5 micrometers. Of the three soils, soil 89-65 (76% quartz) (see Figure 4) displays the most pronounced spectral evidence for quartz. In this case, the strong quartz doublet at 8.6 micrometers is distorted by the presence of clay minerals adhering to quartz grains that produces a third peak centered near 9.4 micrometers.

Particle size has a pronounced effect on spectral behavior (Lyon, R.J.P., 1964). The prominent reflectance peaks between 8 and 10 micrometers are reduced in intensity as particle size decreases (see Figure 8). Salisbury and Eastes (1985) proposed a rationale based on sample porosity to explain this effect. They suggested that the increased porosity produced with decreasing particle size resulted in the formation of photon traps. Increased porosity allows more photons to pass between grains and to penetrate deeper into a particulate sample. A greater depth of penetration results in increased absorption and, therefore, in decreased reflectance. This effect is illustrated in the spectra of soils 89-65 and 89-37 (see Figure 4) where relatively high reflectance occurs between 8 and 10 micrometers for the medium-grained soil 89-65, (see Figure 4) while the fine-grained soil 89-37 exhibits low reflectance in this region. This is analogous to the spectral behavior of carbon black or gold black in the visible, where highly opaque materials also show low reflectance at very fine particle size.

Spectra in Figures 9 and 10 illustrate instances in which surface species unrelated to a substrate may distort or obscure spectral features associated with substrate composition. Such data can be misleading for general compositional analysis; however, for certain remote sensing applications, such as mapping surface contamination, e.g. oil spills, spectral differences can serve to delineate boundaries between contaminated and uncontaminated areas. Figure 9 shows the spectrum of oil contaminated quartzite from an area of the Exxon/Valdez oil spill. The quartz fundamental doublet centered at 8.6 micrometers is prominent, but its longer wavelength lobe is distorted owing to oil film. Specific evidence for organic matter is seen in a feature near 3.4 micrometers due to hydrocarbon C-H stretching vibrations.

Desert varnish is a slow-forming, clay-rich, natural coating often found on rock surfaces in arid regions. In the 8- to 14- micrometer wavelength region, spectral features attributable to clay minerals often dominate the spectra of heavily varnished rocks. Figure 10 shows spectra of fresh and heavily varnished quartzite surfaces. In the spectrum of the varnished sample, the characteristic quartz doublet has been totally replaced by a strong clay feature near 9.4 micrometers. As a result, remote sensing data acquired over a varnished terrain may be misleading.

High surface salinity may also alter the spectral characteristics of a terrain. (Eastes, 1989). Figure 11 illustrates the spectra of pure solid quartz and a 10 percent mixture of finely particulate quartz dispersed in $NaCl$. Here, in the spectral region, between 8.0 and 9.5 micrometers, the reflectance of solid quartz is at a maximum, while that of the particulate mixture passes through a minimum. This effect is exemplified in a natural sample, by the solid trace in Figure 12 that depicts reflectance of an approximately 1-mm thick saline efflorescence associated with a sample of Mojave desert playa material. The dot-dash trace is a similar spectrum of the primarily silicate subcrustal material. Again, in the region between 8 and 10 micrometers, the reflectance of the saline efflorescence is at a minimum, while that of the non-saline component is at a maximum. The depression in reflectance of the saline crust is undoubtedly due to absorption by such species as finely particulate quartz, gypsum, clays and other silicate matter dispersed in the crust. Such materials are introduced by either wind or water.

Environmental Factors. Many factors other than spectral emissivities of materials influence the detected emittance in realistic remote sensing situations. Of these, background radiance is probably the largest factor affecting spectral emittance in the terrestrial environment. Infrared radiance from a cloudy

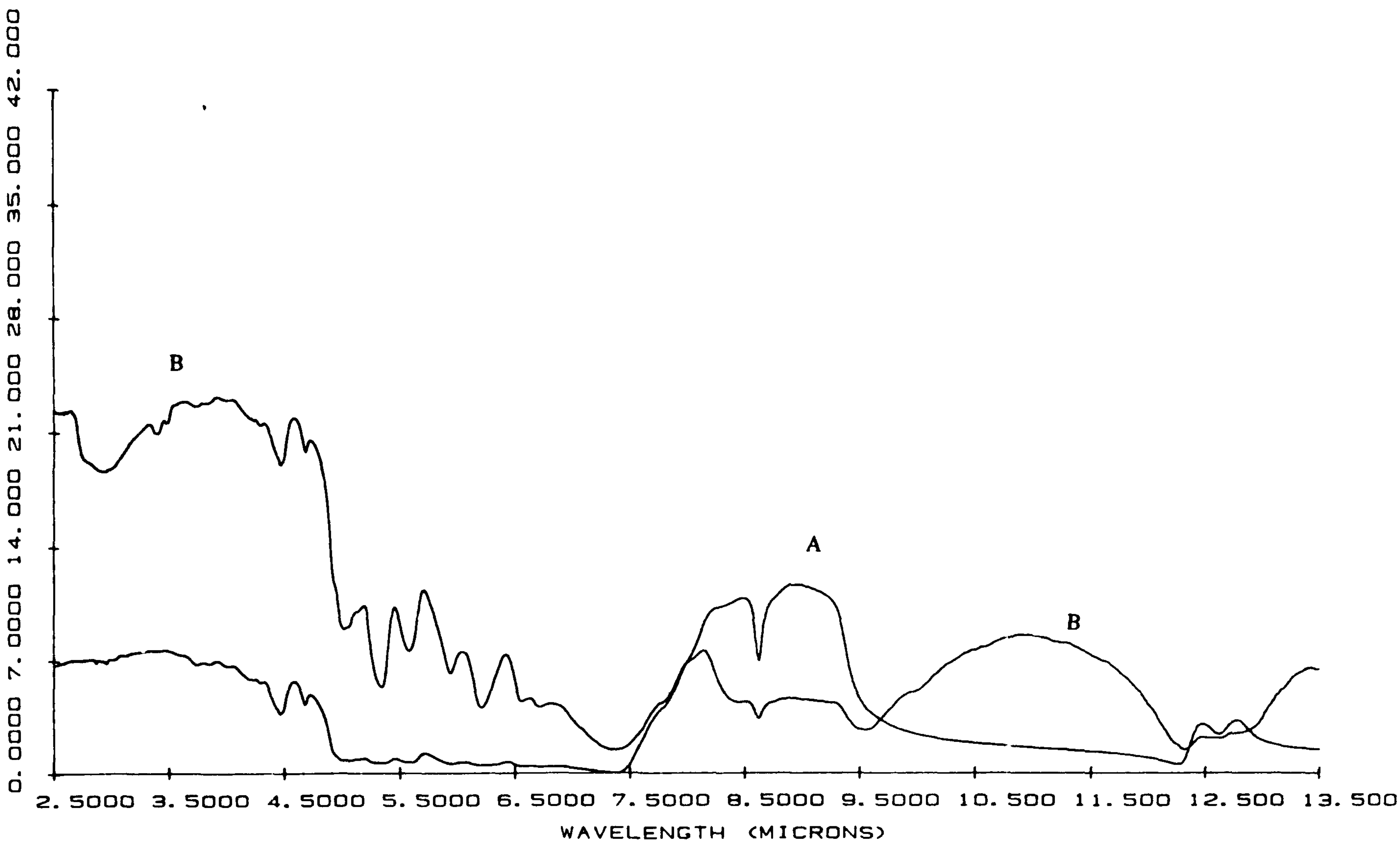

Figure 8. Reflectance of quartz. Trace A -- 74-250 micrometer particles. Trace B -- < 5 micrometer particles.

Note: Feature at 12.5 micrometers is expressed as a reflectance maximum for the 74-250 micrometer particles, but as a minimum for the < 5 nm particles.

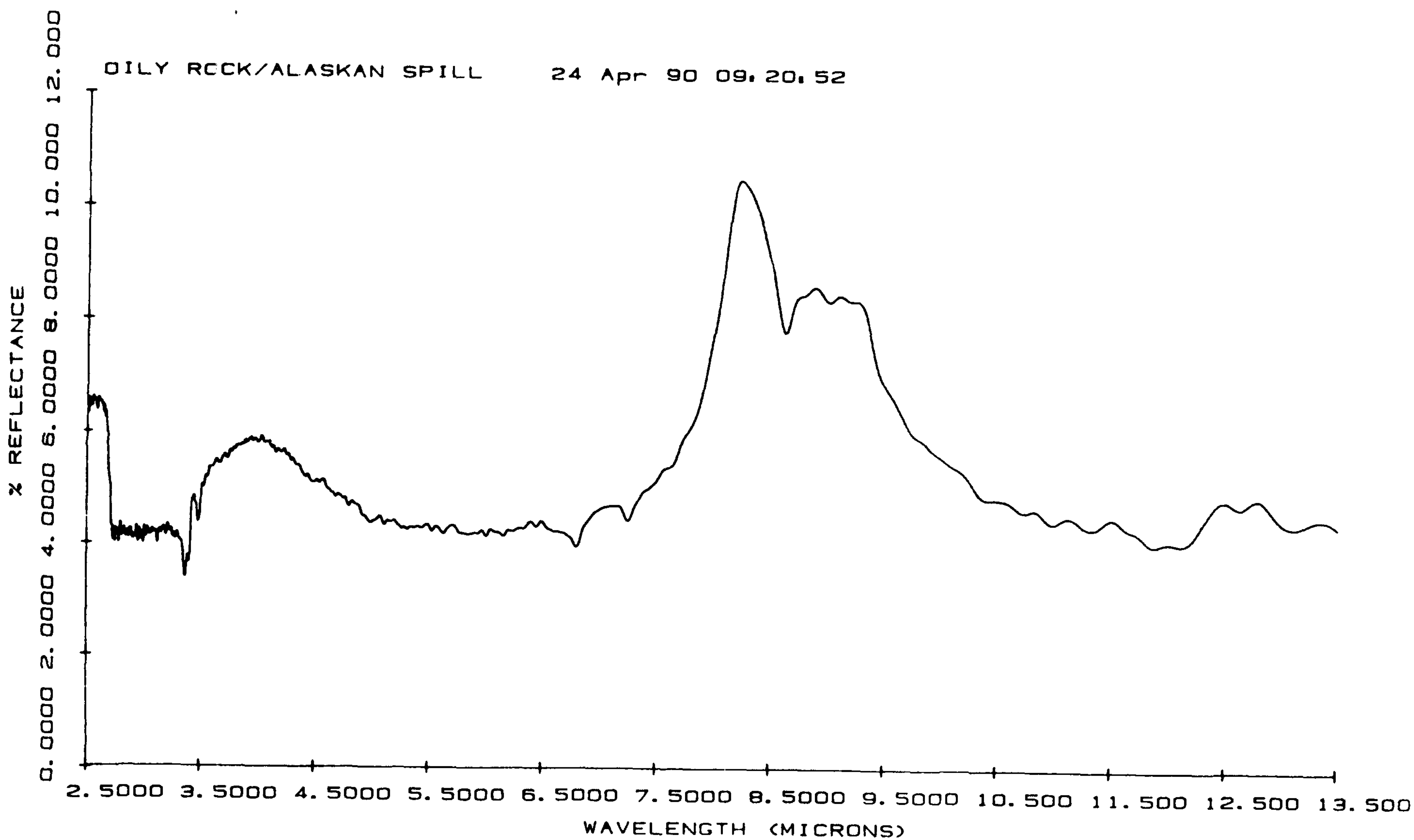

Figure 9. Reflectance of oil-contaminated silicate rock.

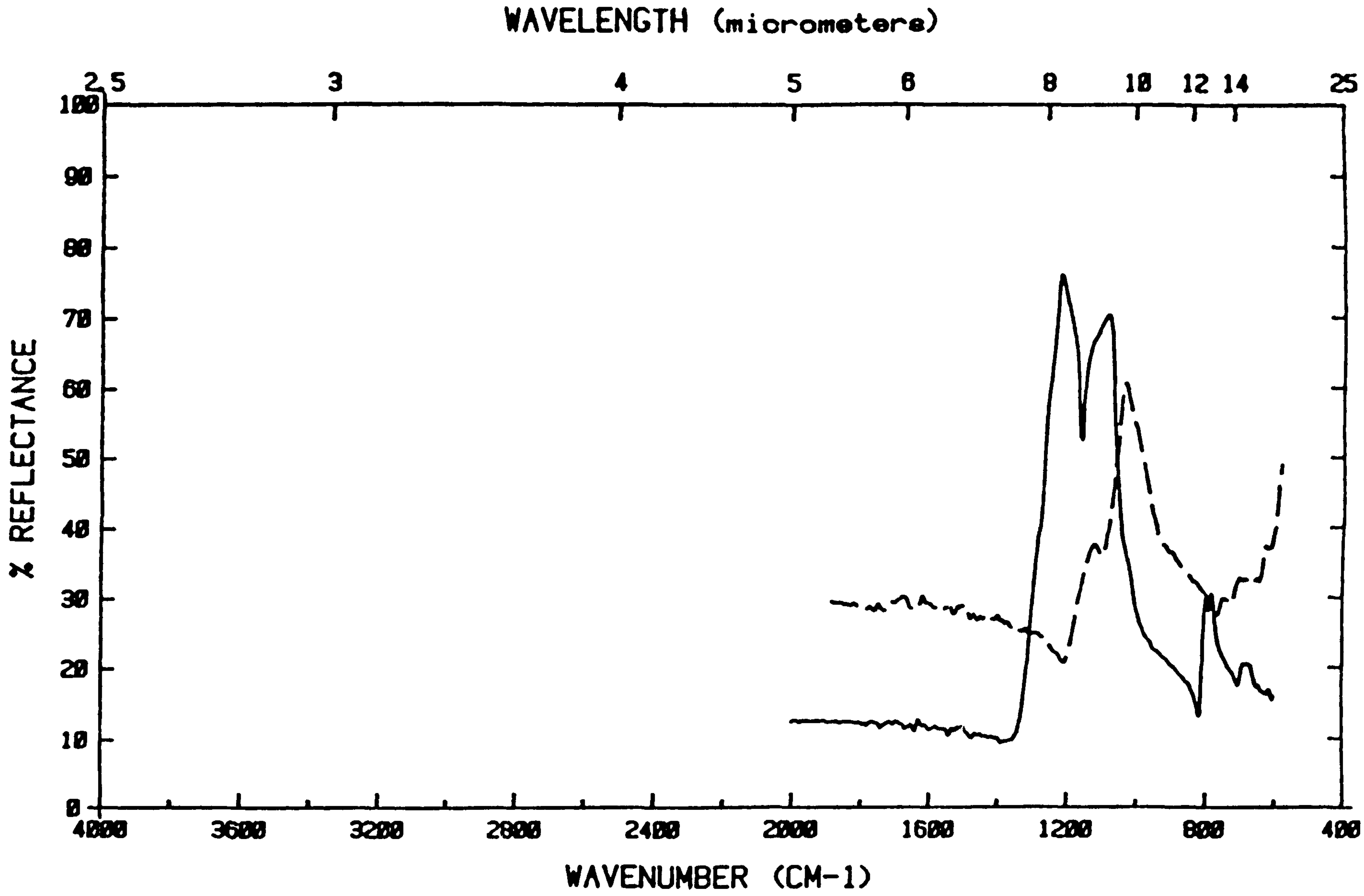

Figure 10. Alteration of spectral features due to desert varnish.

Note: Solid trace: spectrum of unvarnished quartzite.

Dashed trace: spectrum of heavily varnished quartzite.

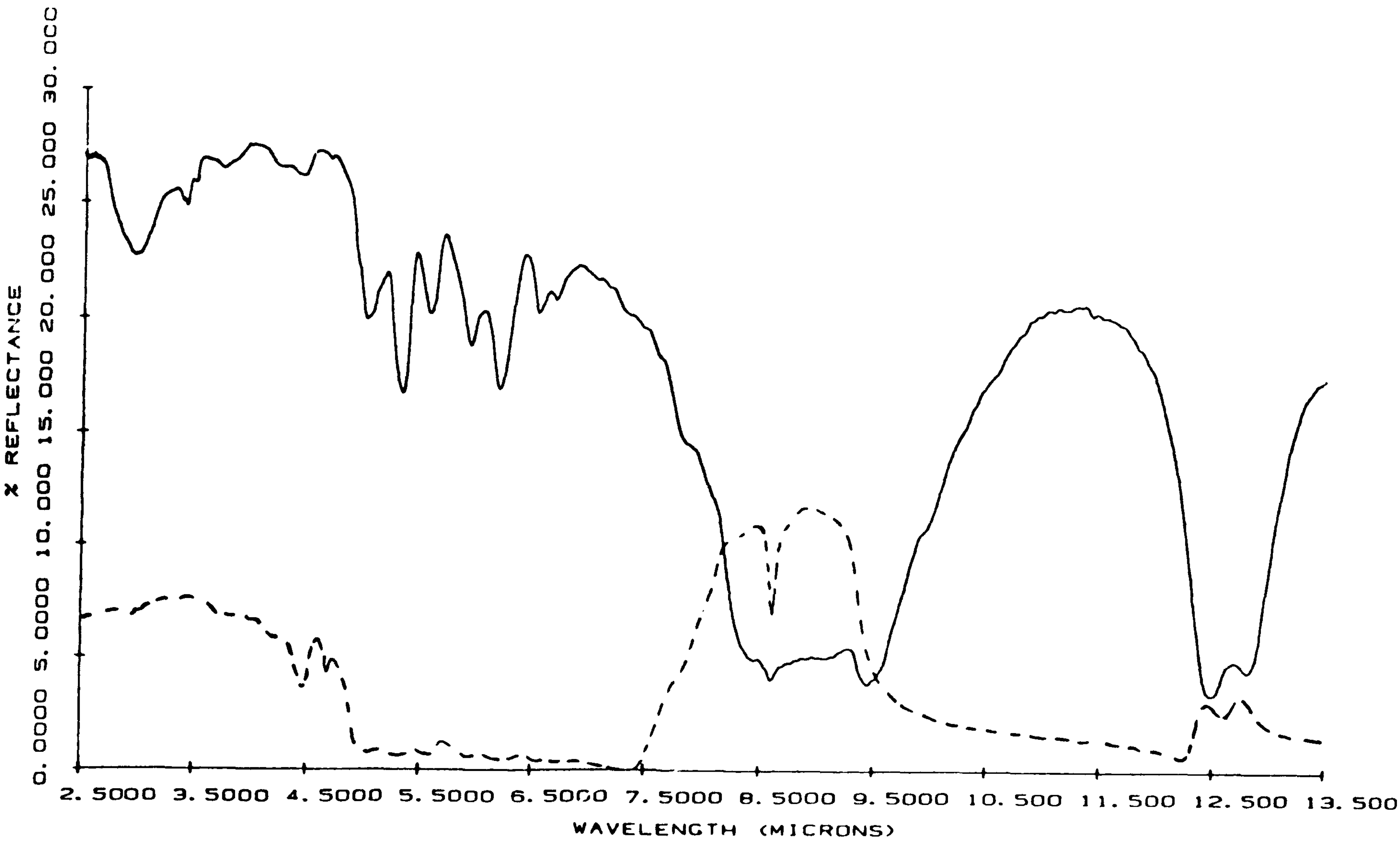

Figure 11. Effects of high salinity on spectral properties of a mineral.

Note: Dashed trace - spectrum of massive quartz. Solid trace - spectrum of 10% finely particulate quartz dispersed in halite (NaCl).

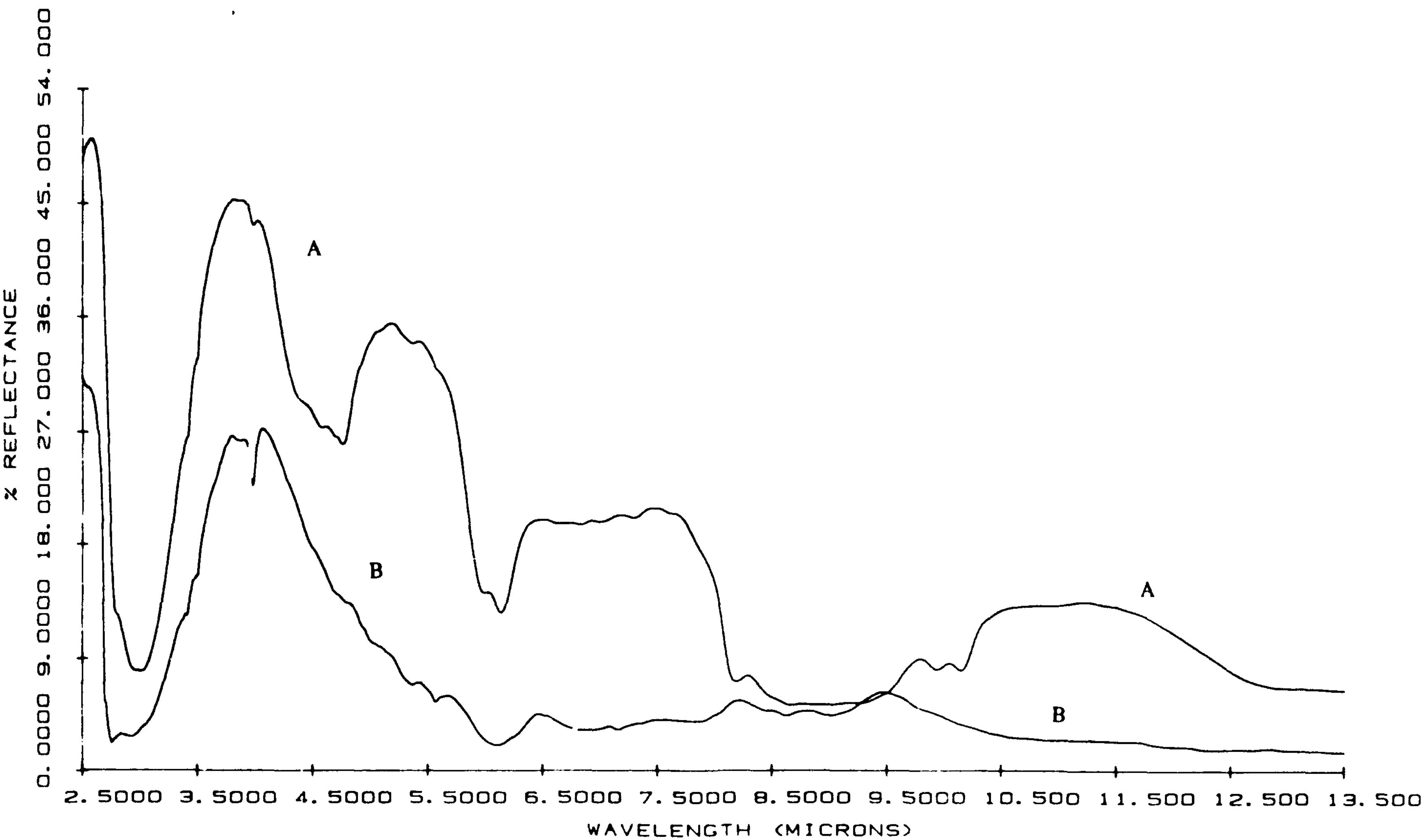

Figure 12. Reflectance of saline playa material.

Note: Trace A -- Reflectance of saline crust. Trace B -- reflectance of associated subcrust.

sky or from background objects reflected from a target will serve to dilute and alter its emitted spectral signature, because the target reflects most where it emits least and vice versa. In a natural environment, wind or terrain conditions that affect heat flow introduce a new set of parameters that can be critical in many situations. In still air, phenomena exist that may affect spectral contrast; for example, diffusion and convection that occur near the leaf surfaces of trees and plants. Air and plant moisture content partially determine the detectable radiation from foliage.

CONCLUSIONS

1. Spectral features appearing in either, or both, the 3 to 5 micrometer or the 8 to 14 micrometer atmospheric windows potentially allow many of the materials to be identified or discriminated from their background by remote sensing techniques.

2. With more advanced sensors and instrumentation, improved target discrimination based on fine spectral features not resolvable by current remote sensing systems may become possible.

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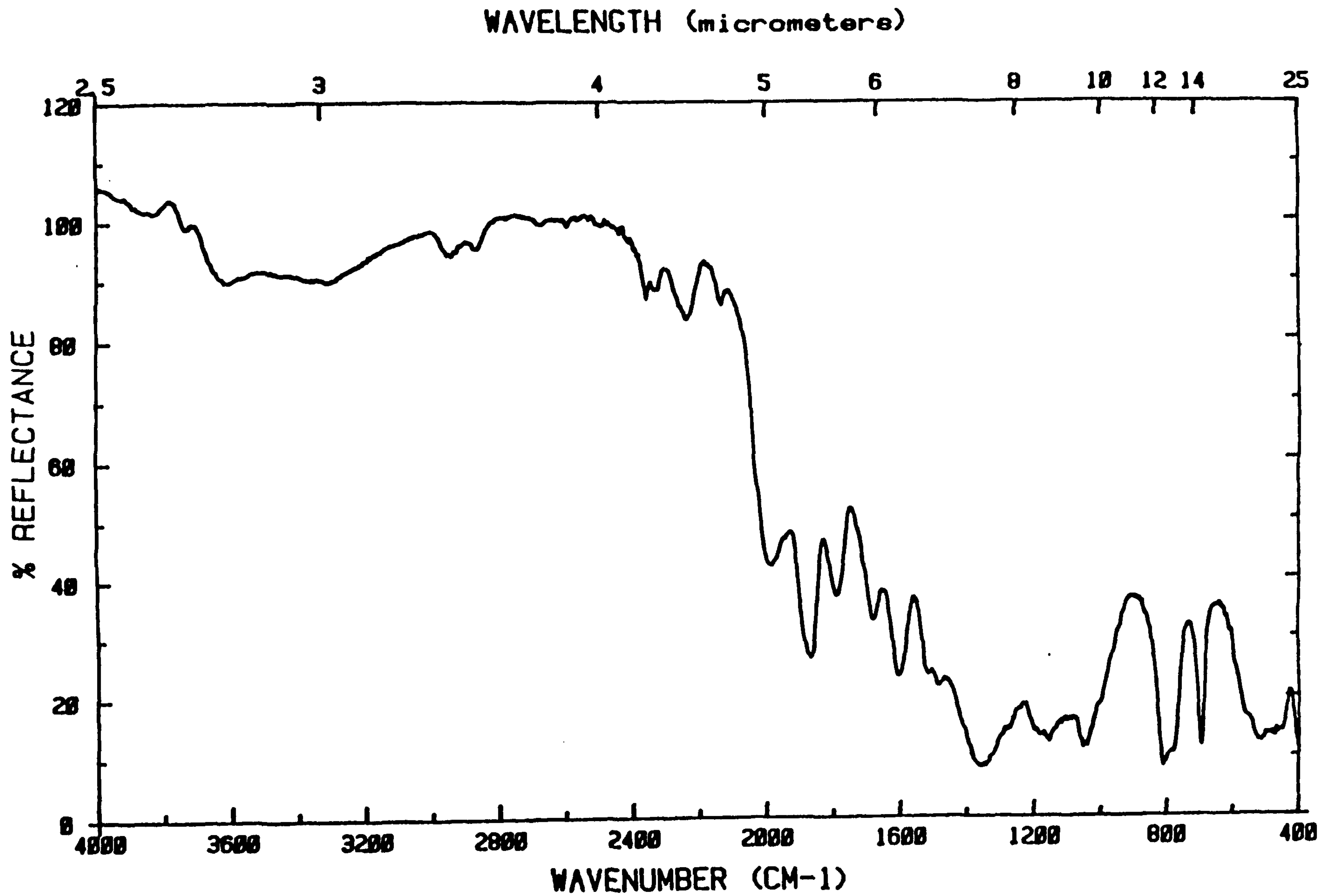
APPENDIX
SPECTRA

SAMPLE TYPE	MATERIAL	PAGE NO.
Minerals	Particulate quartz (0-5 micrometers)	
	Particulate quartz (0-5 micrometers, packed)	
	Particulate quartz (0-74 micrometers)	
	Particulate quartz (74-250 micrometers)	
	Particulate quartz (250-500 micrometers)	
	Particulate calcite (0-5 micrometers)	
	Particulate calcite (0-74 micrometers)	
	Particulate calcite (74-250 micrometers)	
	Particulate calcite (250-500 micrometers)	
	Particulate gypsum (0-5 micrometers)	
	Particulate gypsum (0-74 micrometers)	
	Particulate gypsum (74-250 micrometers)	
	Particulate gypsum (250-500 micrometers)	
	Montmorillonite	
Saline samples	2% 0-5 micrometer quartz in NaCl	
	10% 0-5 micrometer quartz in NaCl	
	25% 0-5 micrometer quartz in NaCl	
	50% 0-5 micrometer quartz in NaCl	
	2% 0-75 micrometer quartz in NaCl	
	15% 0-75 micrometer quartz in NaCl	
	25% 0-75 micrometer quartz in NaCl	
	50% 0-75 micrometer quartz in NaCl	
	2% 75-250 micrometer quartz in NaCl	
	10% 75-250 micrometer quartz in NaCl	
	15% 75-250 micrometer quartz in NaCl	
	25% 75-250 micrometer quartz in NaCl	
	50% 75-250 micrometer quartz in NaCl	
	2% 0-5 micrometer calcite in NaCl	
	10% 0-5 micrometer calcite in NaCl	
	25% 0-5 micrometer calcite in NaCl	
	50% 0-5 micrometer calcite in NaCl	
	2% 0-74 micrometer calcite in NaCl	
	10% 0-74 micrometer calcite in NaCl	
	25% 0-74 micrometer calcite in NaCl	
	50% 0-74 micrometer calcite in NaCl	
	2% 74-250 micrometer calcite in NaCl	
	10% 74-250 micrometer calcite in NaCl	
	25% 74-250 micrometer calcite in NaCl	
	50% 74-250 micrometer calcite in NaCl	

SAMPLE TYPE	MATERIAL	PAGE NO.
Saline Samples	2% 0-5 micrometer gypsum in NaCl	
	10% 0-5 micrometer gypsum in NaCl	
Saline	25% 0-5 micrometer gypsum in NaCL	
	50% 0-5 micrometer gypsum in NaCl	
	2% 0-74 micrometer gypsum in NaCl	
	10% 0-74 micrometer gypsum in NaCl	
	25% 0-74 micrometer gypsum in NaCl	
	50% 0-74 micrometer gypsum in NaCl	
	2% 74-250 micrometer gypsum in NaCl	
	10% 74-250 micrometer gypsum in NaCl	
	25% 74-250 micrometer gypsum in NaCl	
	50% 74-250 micrometer gypsum in NaCl	
	2% montmorillonite in NaCl	
	10% montmorillonite in NaCl	
	25% montmorillonite in NaCl	
	50% montmorillonite in NaCl	
Soil	Soil 89-9.S14	
	Soil 89-17.S18	
	Soil 89-24	
	Soil 89-27.S27	
	Soil 89-31.S16	
	Soil 89-33.S28	
	Soil 89-37.S15	
	Soil 89-38	
	Soil 89-40	
	Soil 89-44.S26	
	Soil 89-51.S10	
	Soil 89-52.S24	
	Soil 89-54.S25	
	Soil 89-66.S29	
	Soil 89-72.S21	
	Soil 89-72B	
	Soil 89-73.S12	
	Soil 89-74.S13	
	Soil 89-75.S11	
	Soil 89-76.S7	
	Soil 89-44.S26	
	Soil 89-51.S10	
	Soil 89-52.S24	
	Soil 89-54.S25	
SAMPLE TYPE	MATERIAL	PAGE NO.

SAMPLE TYPE	MATERIAL	PAGE NO.
	Soil 89-65.S22	
	Soil 89-66.S29	
	Soil 89-72.S21	
	Soil 89-72B	
	Soil 89-73.S12	
	Soil 89-74.S13	
	Soil 89-75.S11	
	Soil 89-76.S7	
	Soil 89-77.S20	
	Soil 89-78.S23	
	Soil 89-79.S8	
	Soil 89-80	
	Soil EL-1	
	Soil USGS #1	
	Soil USGS #2	
	Soil USGS #3	
	Soil USGS #4	
	Soil USGS #5	
	Soil USGS #6	
	Soil USGS #7	
	Soil USGS #8	
	Soil USGS #9	
	Soil USGS #10	
Rock	Carbonate Rock	
	Unvarnished Quartzite #1	
	Unvarnished Quartzite #2	
	Lightly Varnished Quartzite	
	Varnished Quartzite #1	
	Varnished Quartzite #2	
	Varnished Quartzite #3	
	Varnished Quartzite #4	
	Heavily Varnished Quartzite #1	
	Heavily Varnished Quartzite #2	
	Kelso Soil	
	Kelso Soil #5	
	Kelso Soil	
	Dune Sand, Kelso #10	
	Kelso Soil #14	
	Lava, Kelso #2	
	Lava, Hawaiian	
Halite	Halite #1	
	Halite #2	

SAMPLE TYPE	MATERIAL	PAGE NO.
Vegetation	Rhododendron Leaf	
	Cotton Fiber	
Paint	Orange Paint; Camouflage	
Fabric Dye	Light Brown Dye	
	Green Dye	
	Green Dye	
	Dark Brown Dye	
	Black Dye	
Asphalt	Asphalt #1	
	Asphalt #2	



PARTICULATE QUARTZ <5 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

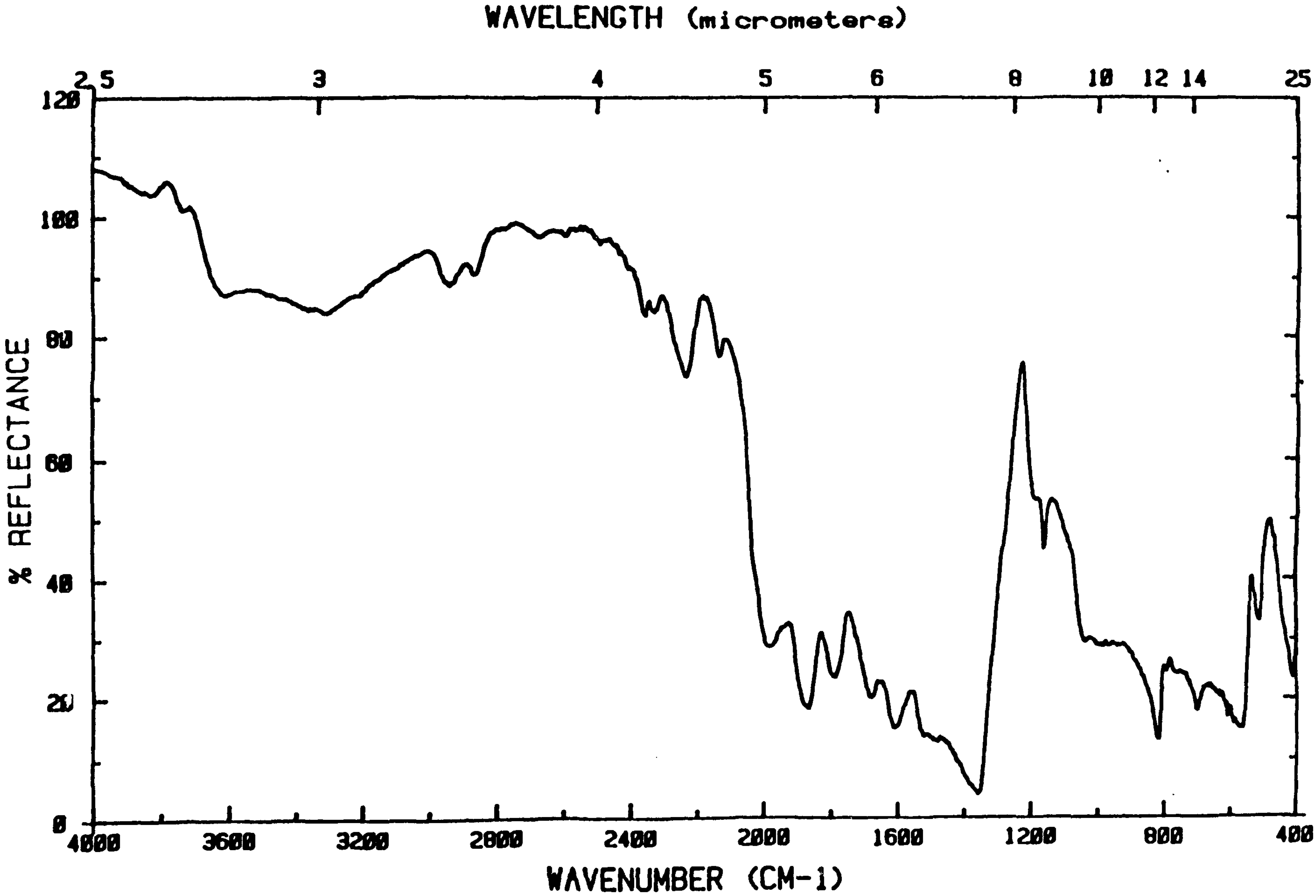
Reference: Particulate KBr (<75 micrometer particle size)

Sample: quartz, <5 micrometer particles

Origin: Rock Springs, Arkansas

Physical state: particulate

Remarks: Sample is pure quartz.



PARTICULATE QUARTZ <5 UM PACKED

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

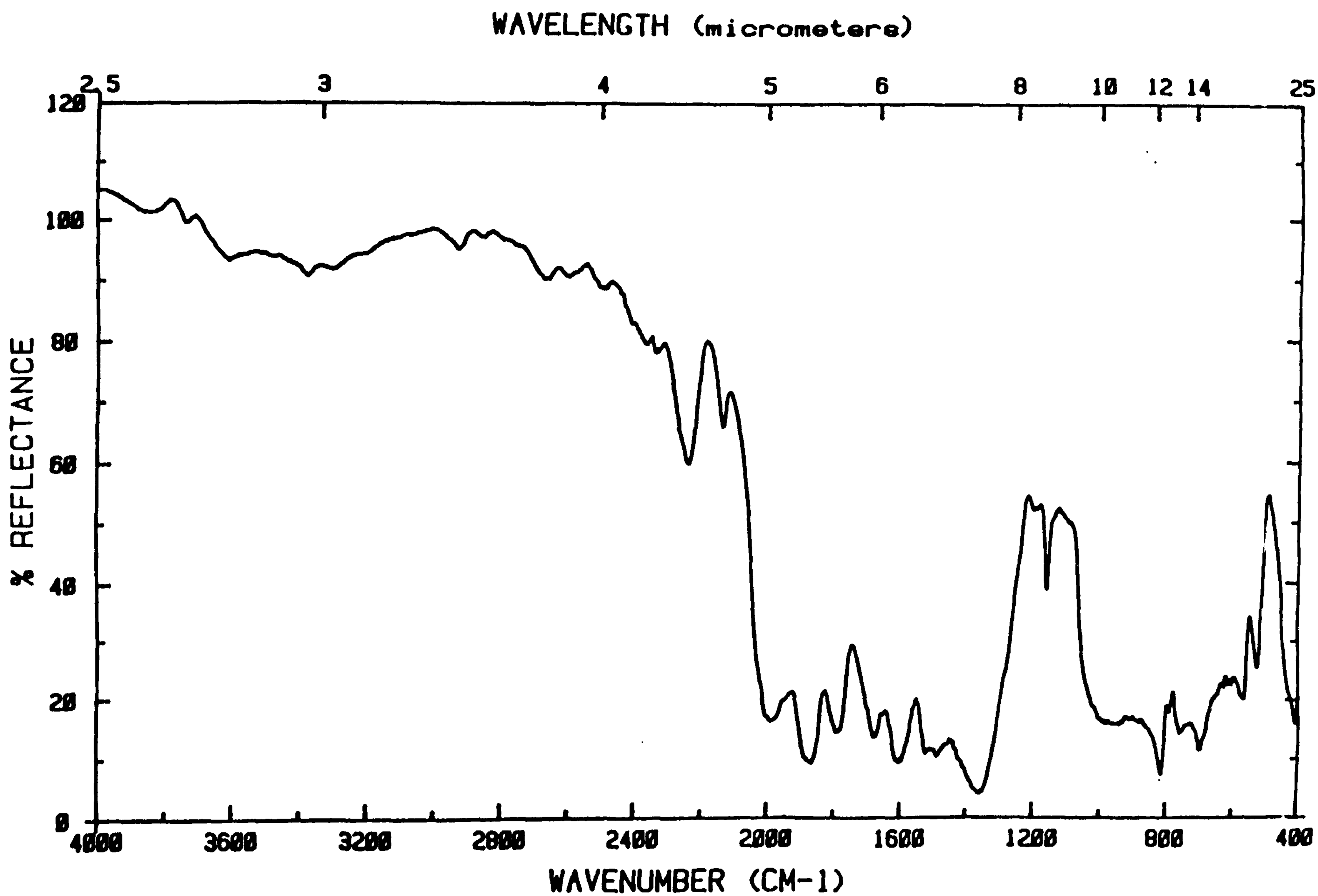
Reference: Particulate KBr (<75 micrometer particle size)

Sample: packed quartz, <5 micrometer particles

Origin: Rock Springs, Arkansas

Physical state: particulate

Remarks: Sample is pure quartz. Sample was compressed to illustrate spectral effects of porosity differences (compare with spectrum of unpacked sample).



PARTICULATE QUARTZ 0-74 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

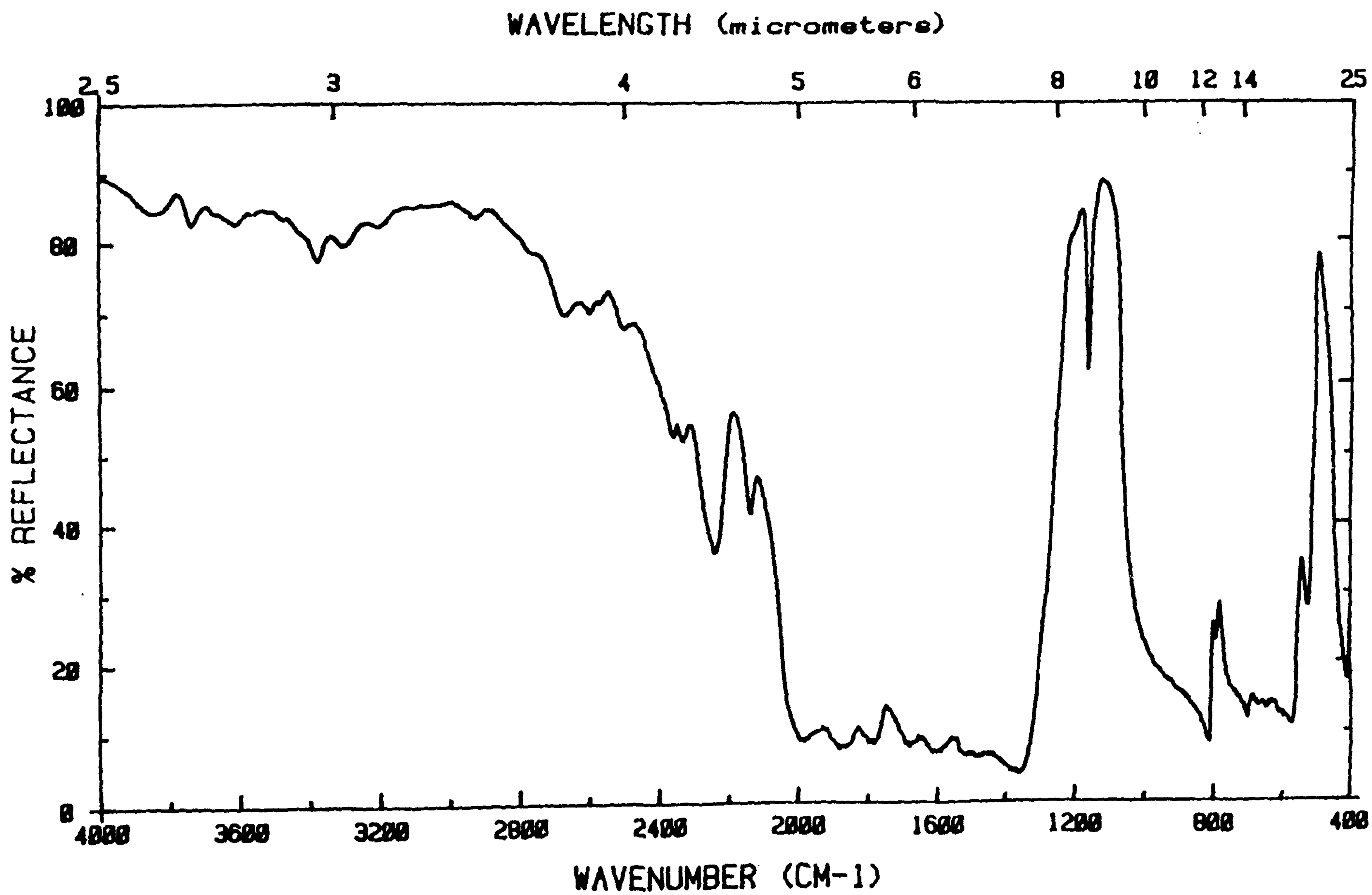
Reference: Particulate KBr (<75 micrometer particle size)

Sample: quartz, <74 micrometer particles

Origin: Rock Springs, Arkansas

Physical state: particulate

Remarks: Sample is pure quartz.



PARTICULATE QUARTZ 74-250 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

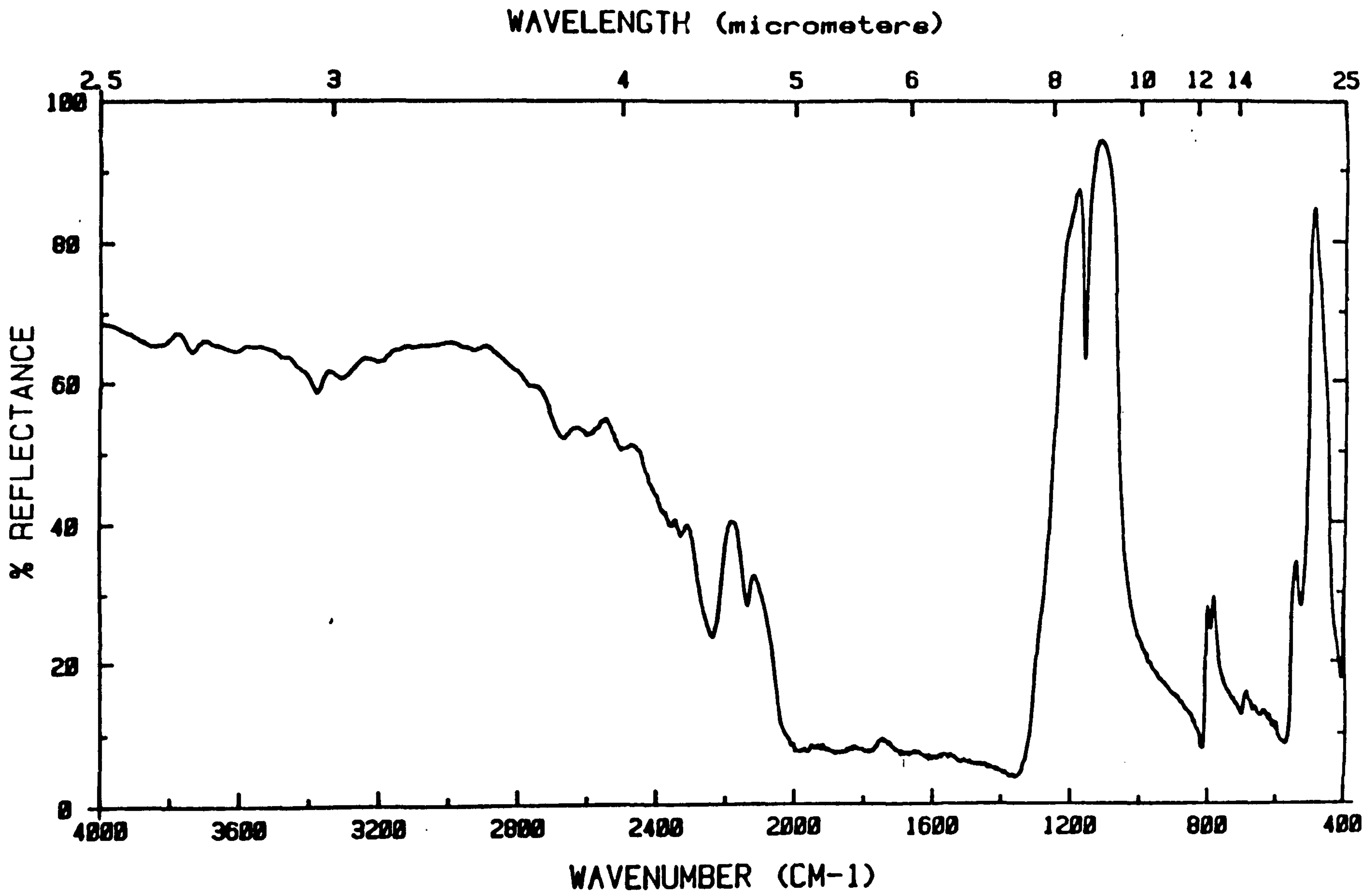
Reference: Particulate KBr (<75 micrometer particle size)

Sample: quartz, 74-250 micrometer particles

Origin: Rock Springs, Arkansas

Physical state: particulate

Remarks: Sample is pure quartz.



PARTICULATE QUARTZ 250-500 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

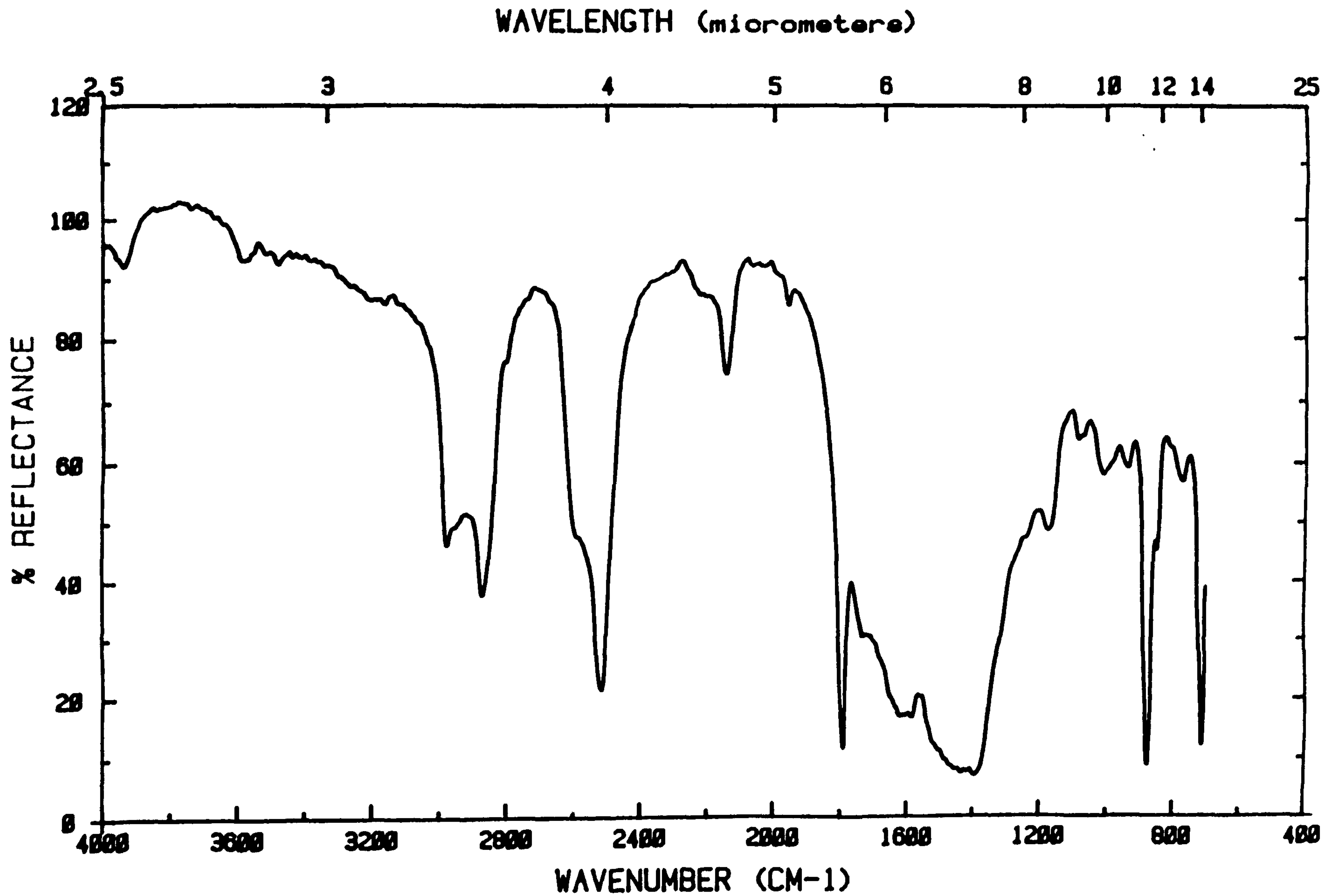
Reference: Particulate KBr (<75 micrometer particle size)

Sample: quartz, 250-500 micrometer particles

Origin: Rock Springs, Arkansas

Physical state: particulate

Remarks: Sample is pure quartz.



CALCITE (0-5 UM PARTICLE SIZE)

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

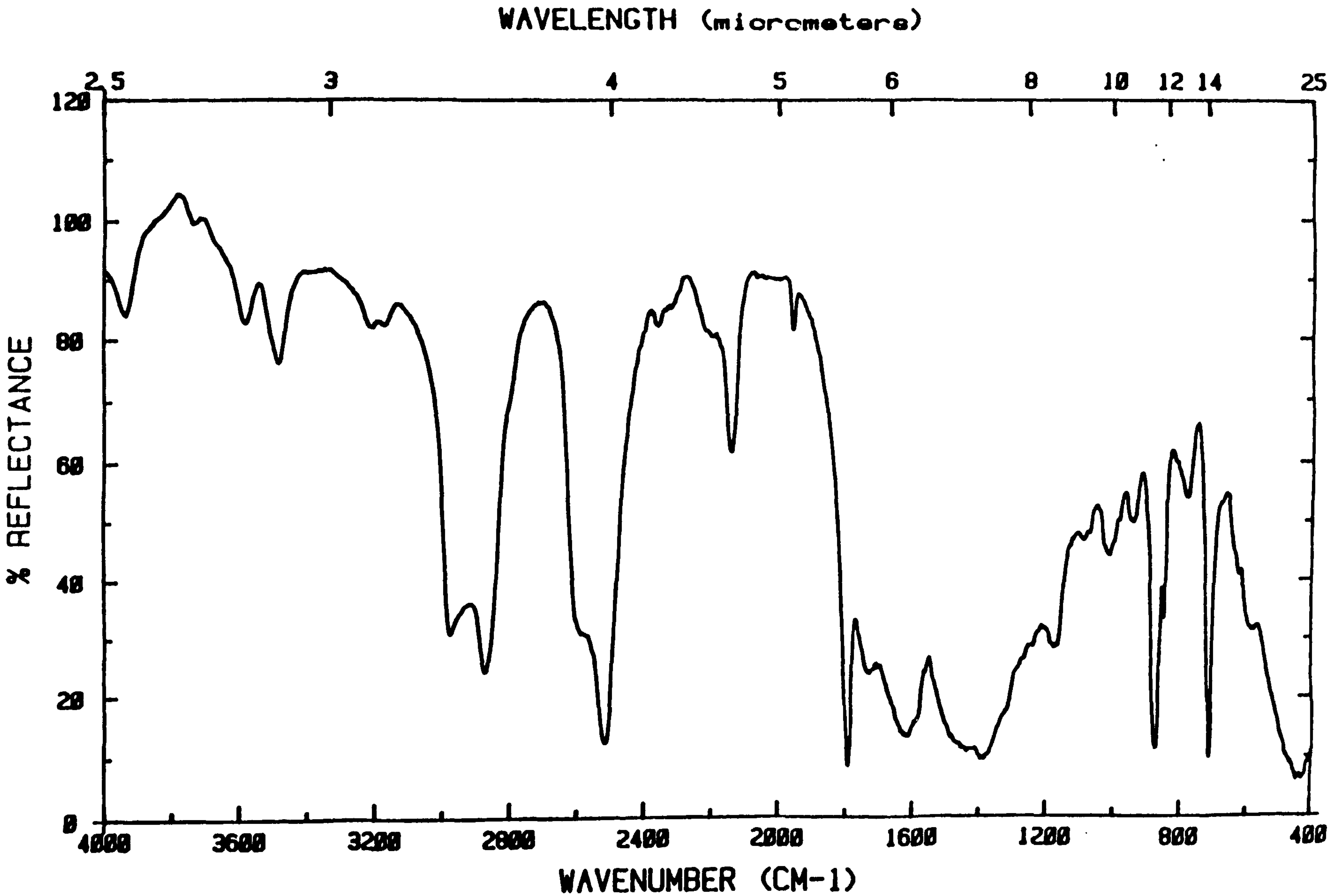
Reference: Particulate KBr (<75 micrometer particle size)

Sample: calcite <5 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure calcite.



PARTICULATE CALCITE 0-74 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

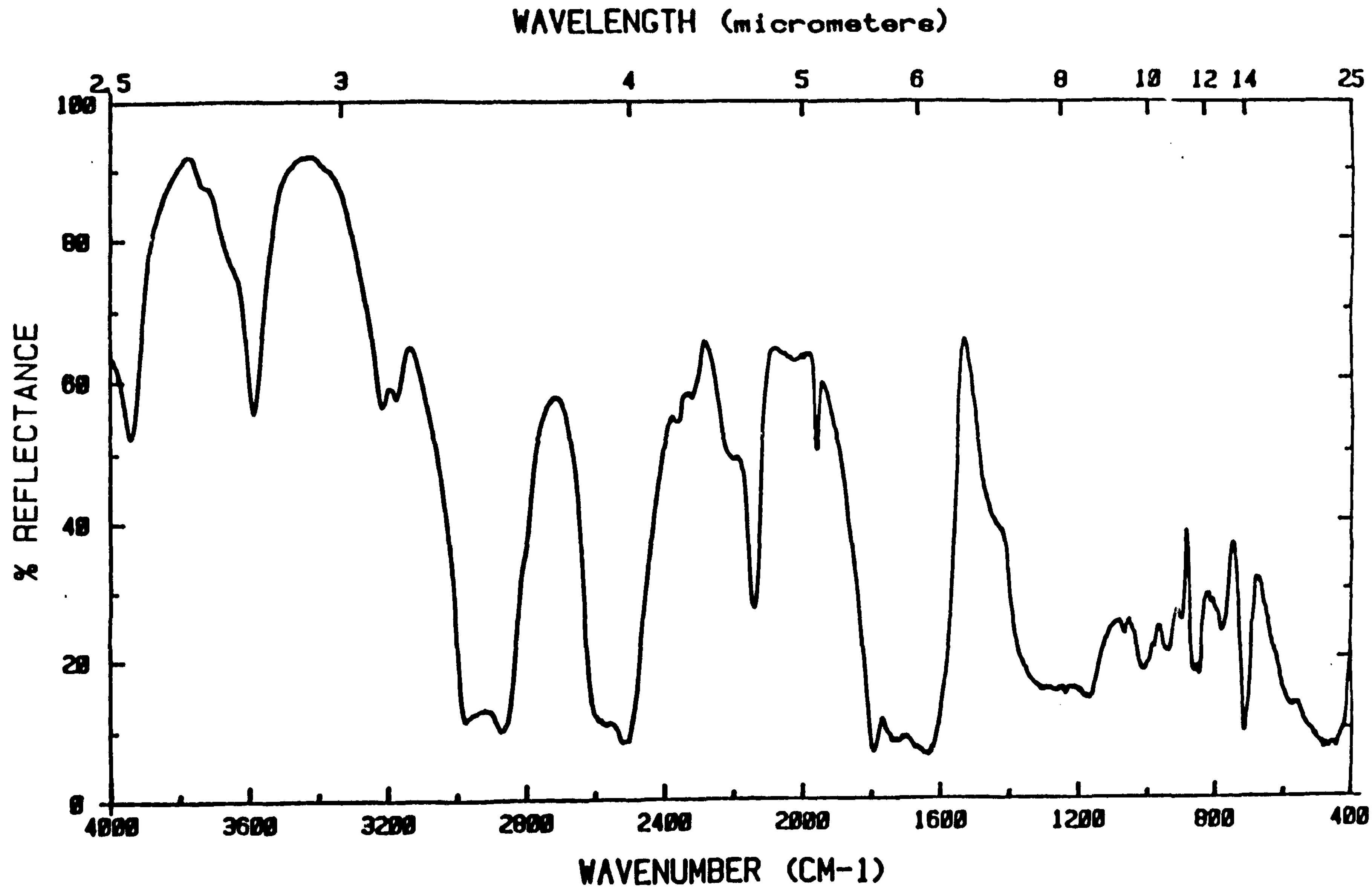
Reference: Particulate KBr (<75 micrometer particle size)

Sample: calcite <74 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure calcite.



PARTICULATE CALCITE 74-250 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

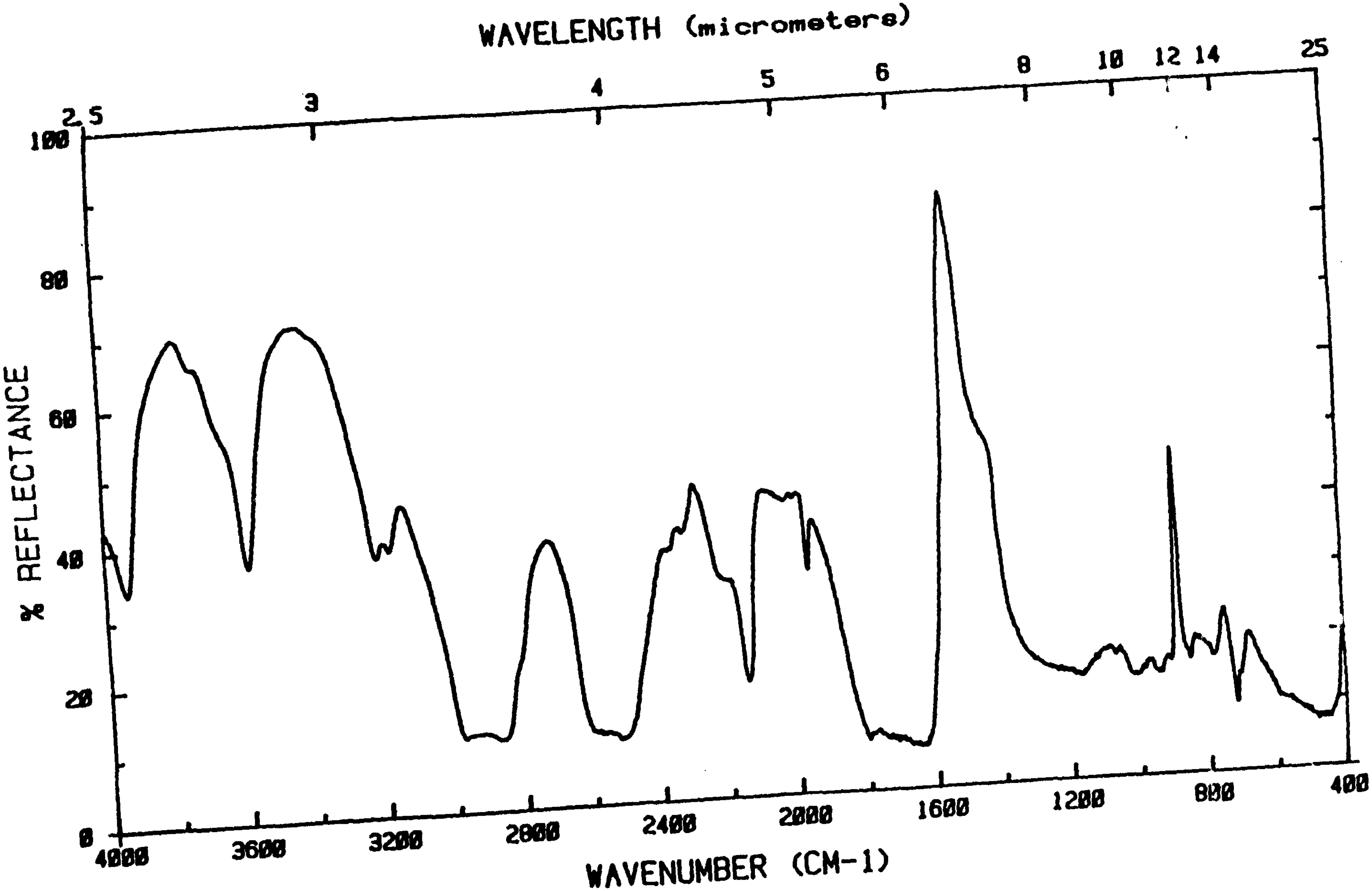
Reference: Particulate KBr (<75 micrometer particle size)

Sample: calcite 74-250 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure calcite.



PARTICULATE CALCITE 250-500 UM

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

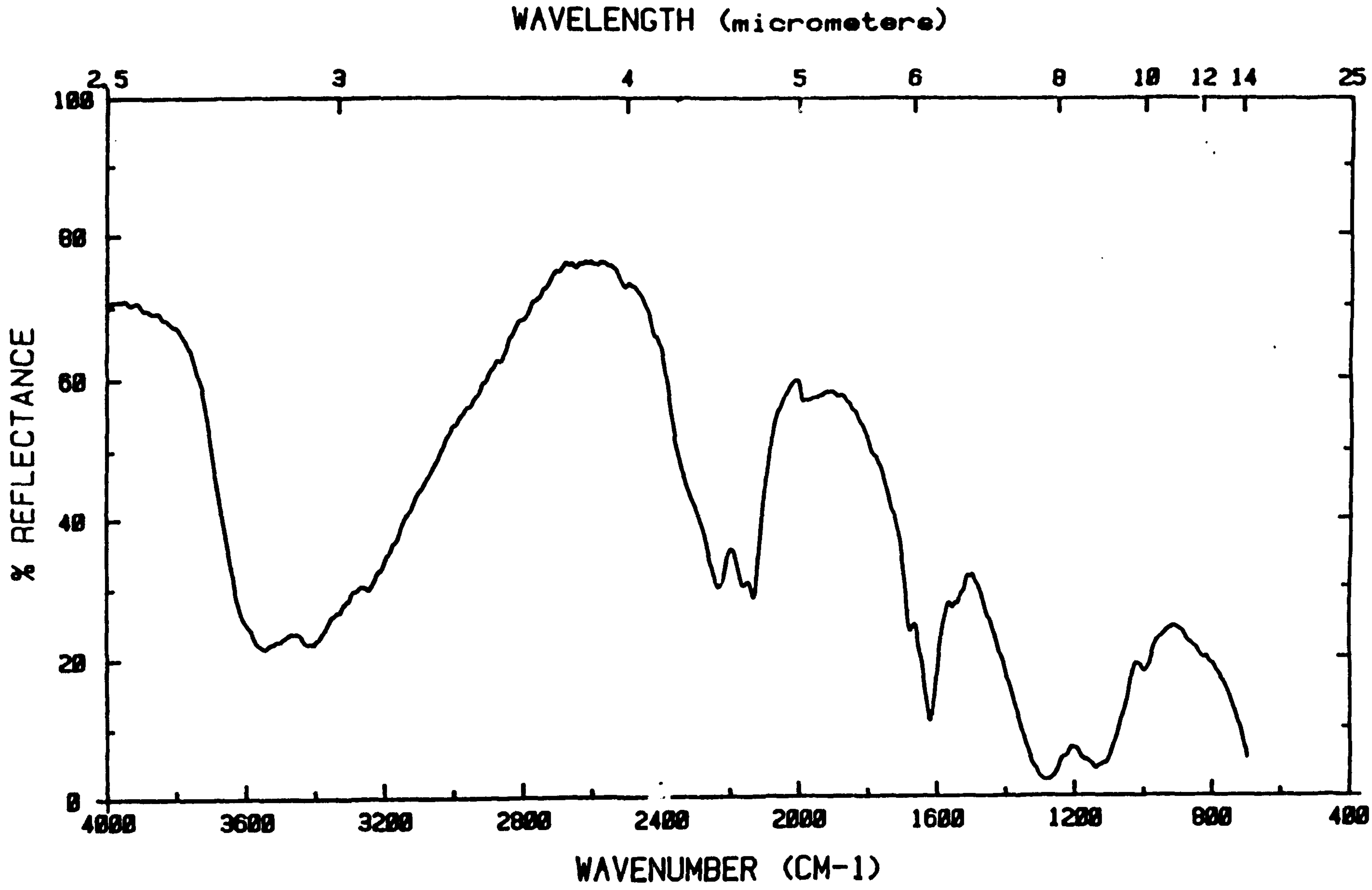
Reference: Particulate KBr (<75 micrometer particle size)

Sample: calcite 250-500 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure calcite.



GYPSUM (0-5 UM PARTICLE SIZE)

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

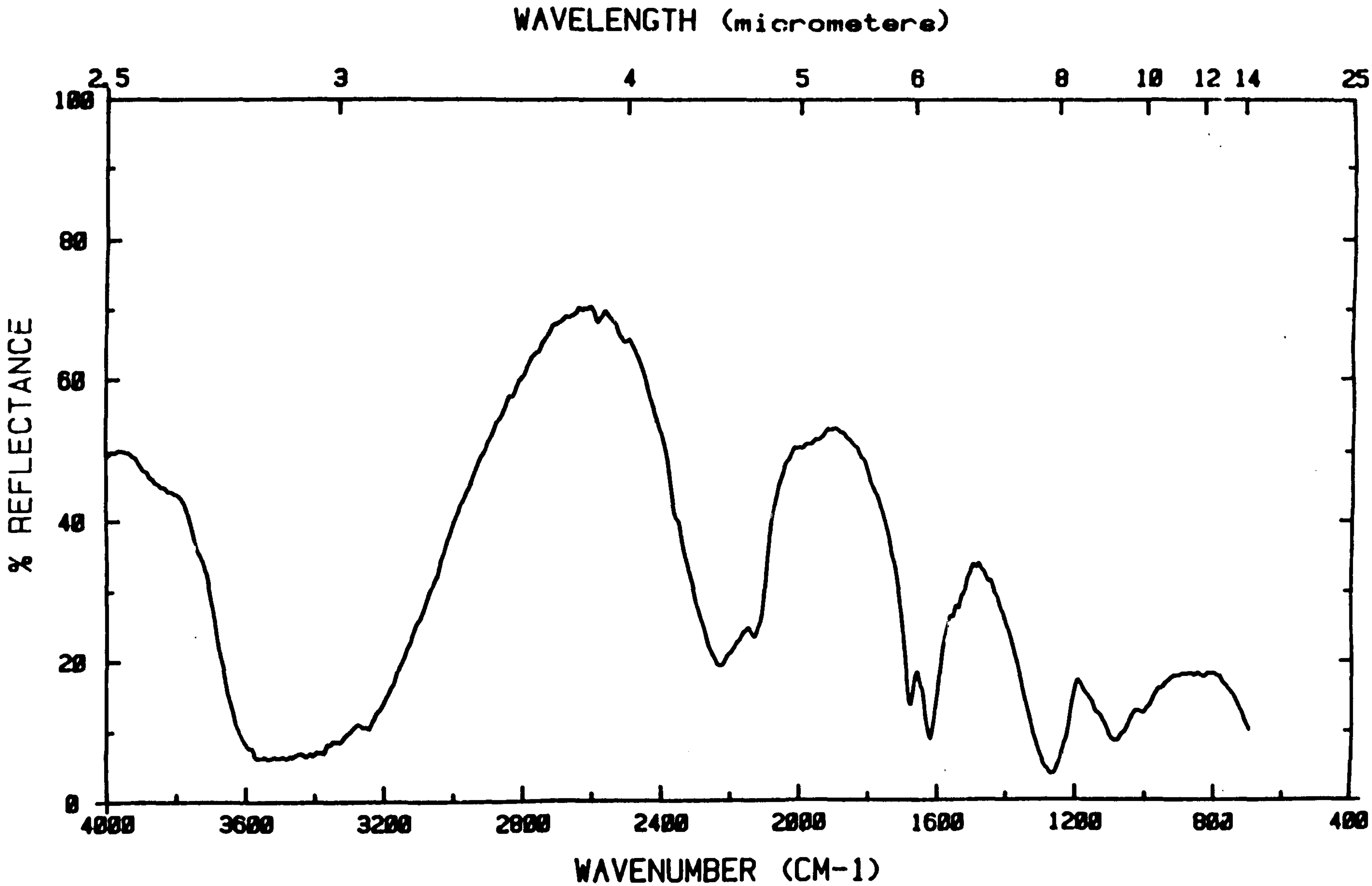
Reference: Particulate KBr (<75 micrometer particle size)

Sample: gypsum <5 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure gypsum.



GYPSUM (0-74 UM PARTICLE SIZE)

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

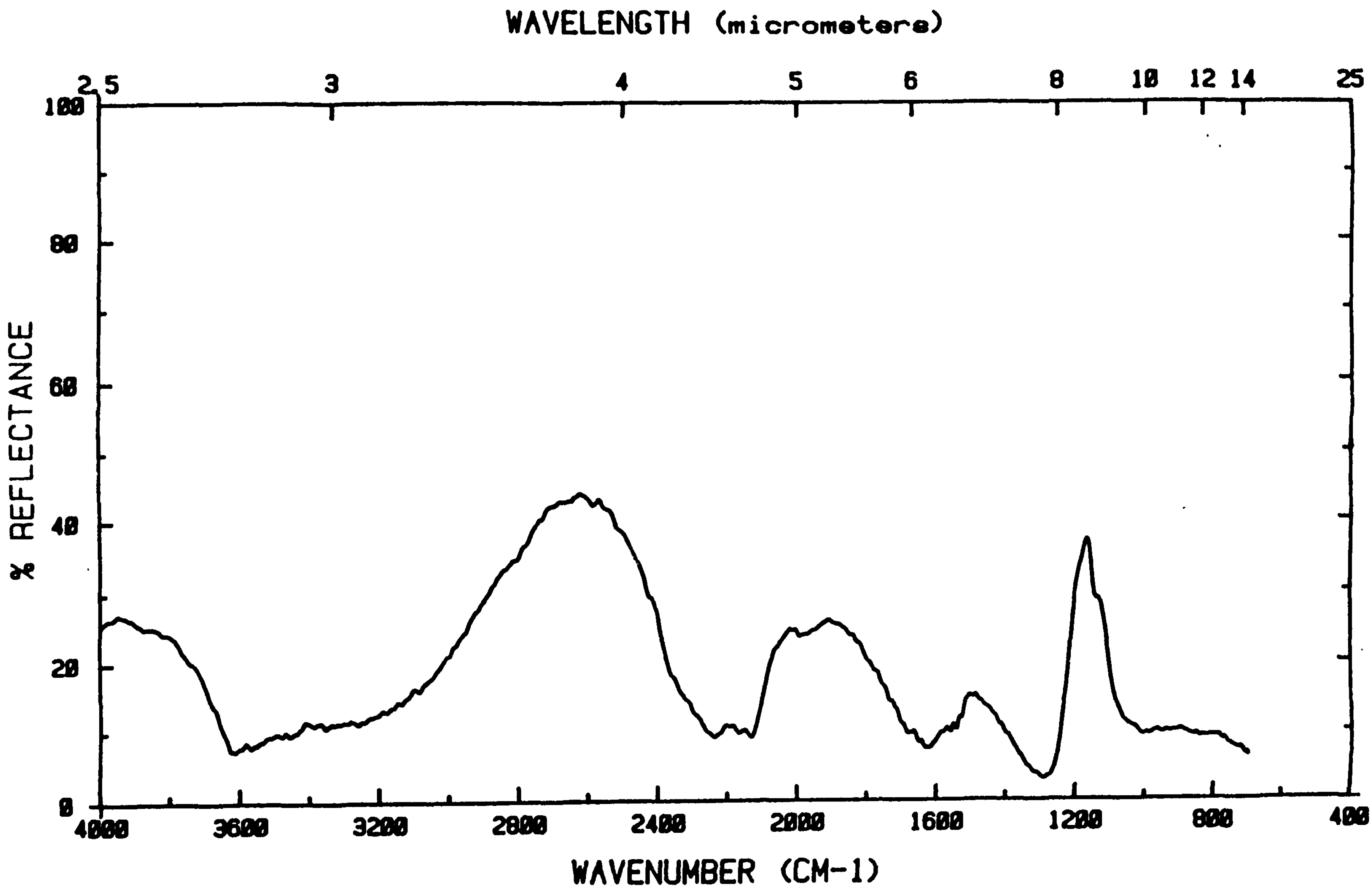
Reference: Particulate KBr (<75 micrometer particle size)

Sample: gypsum <74 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure gypsum.



GYPSUM (74-250 UM PARTICLE SIZE)

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

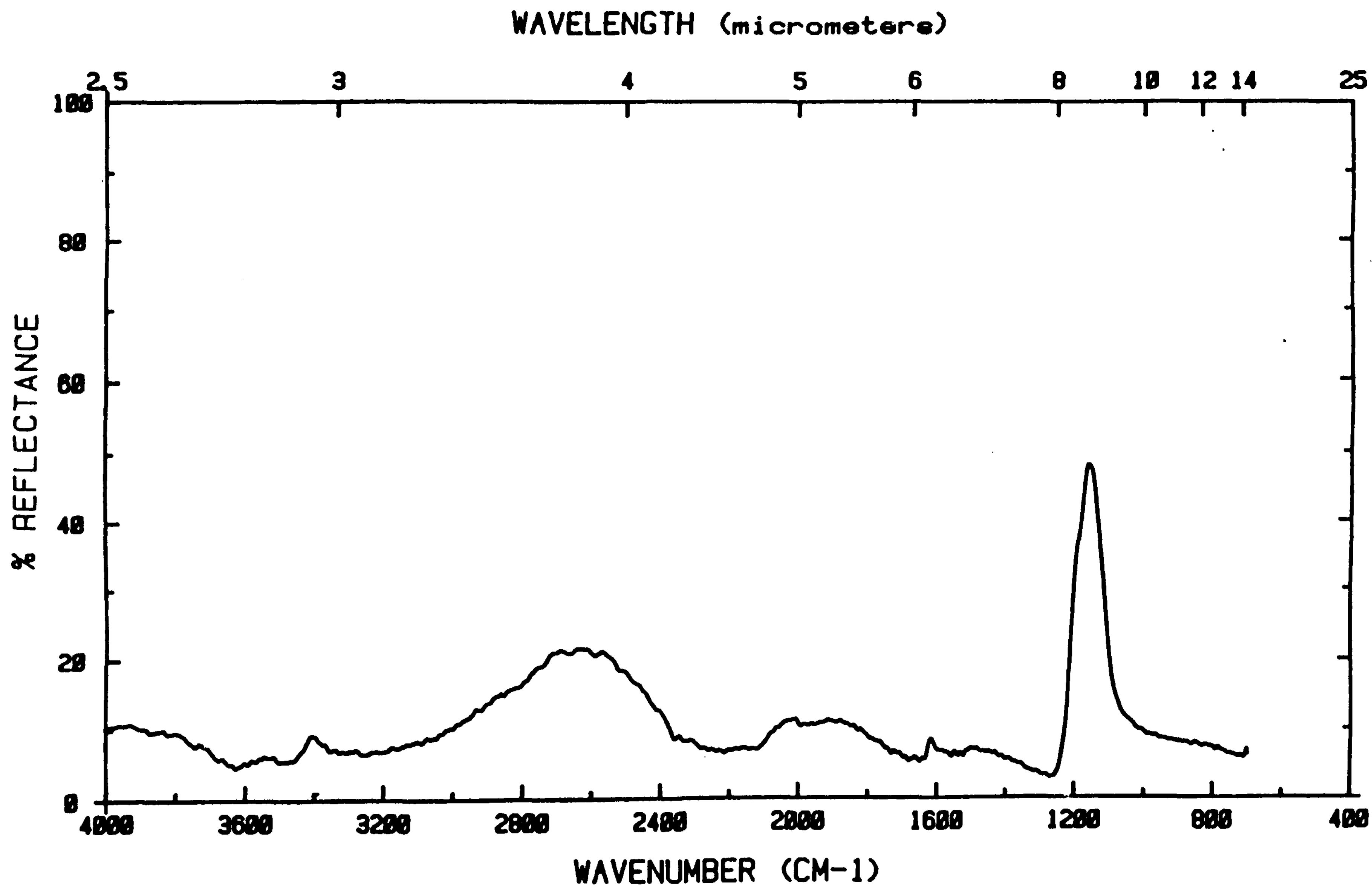
Reference: Particulate KBr (<75 micrometer particle size)

Sample: gypsum 74-250 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure gypsum.



GYPSUM (250-500 UM PARTICLE SIZE)

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

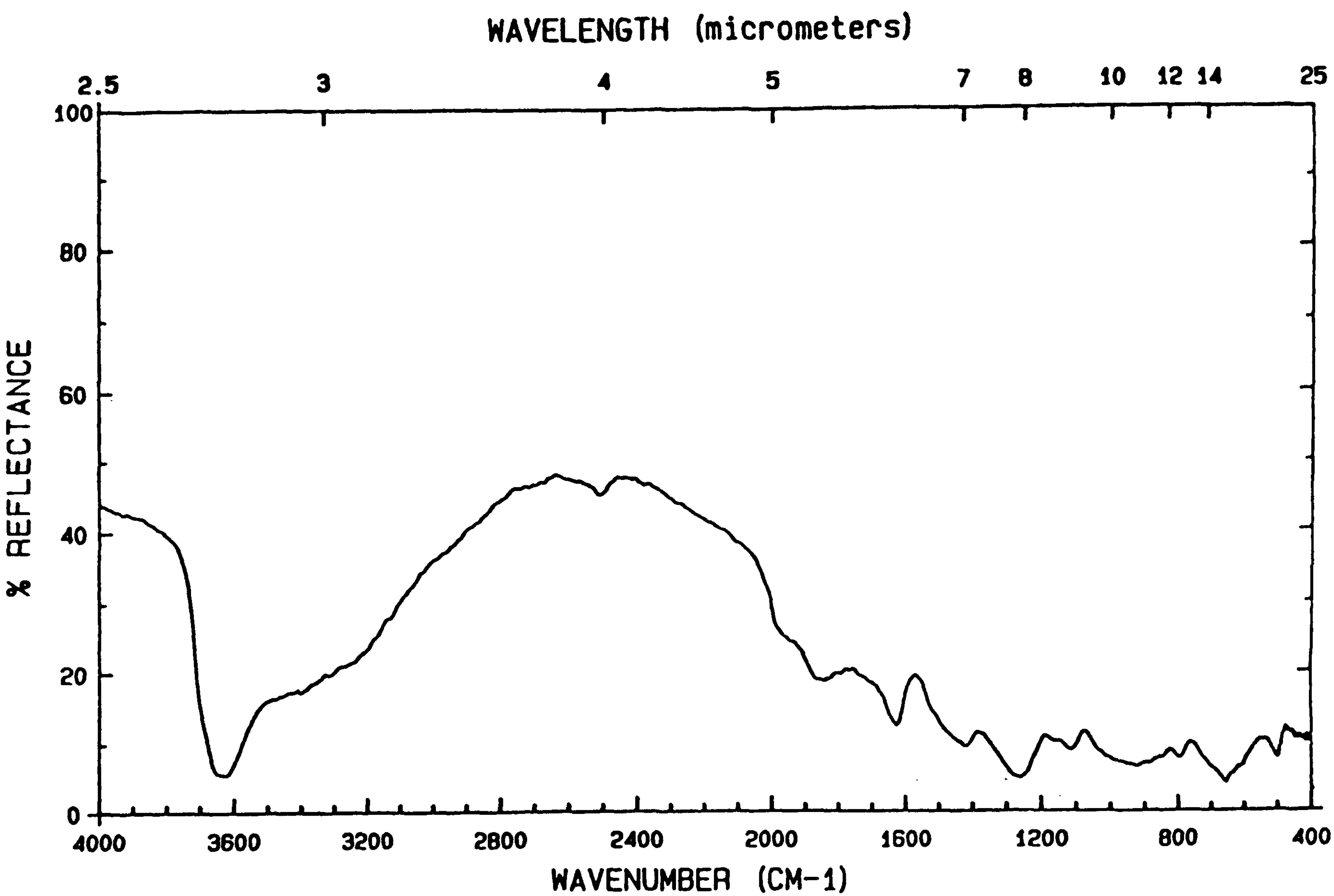
Reference: Particulate KBr (<75 micrometer particle size)

Sample: gypsum 250-500 micrometer particles

Origin: Mexico

Physical state: particulate

Remarks: Sample is pure gypsum.



MONTMORILLONITE

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

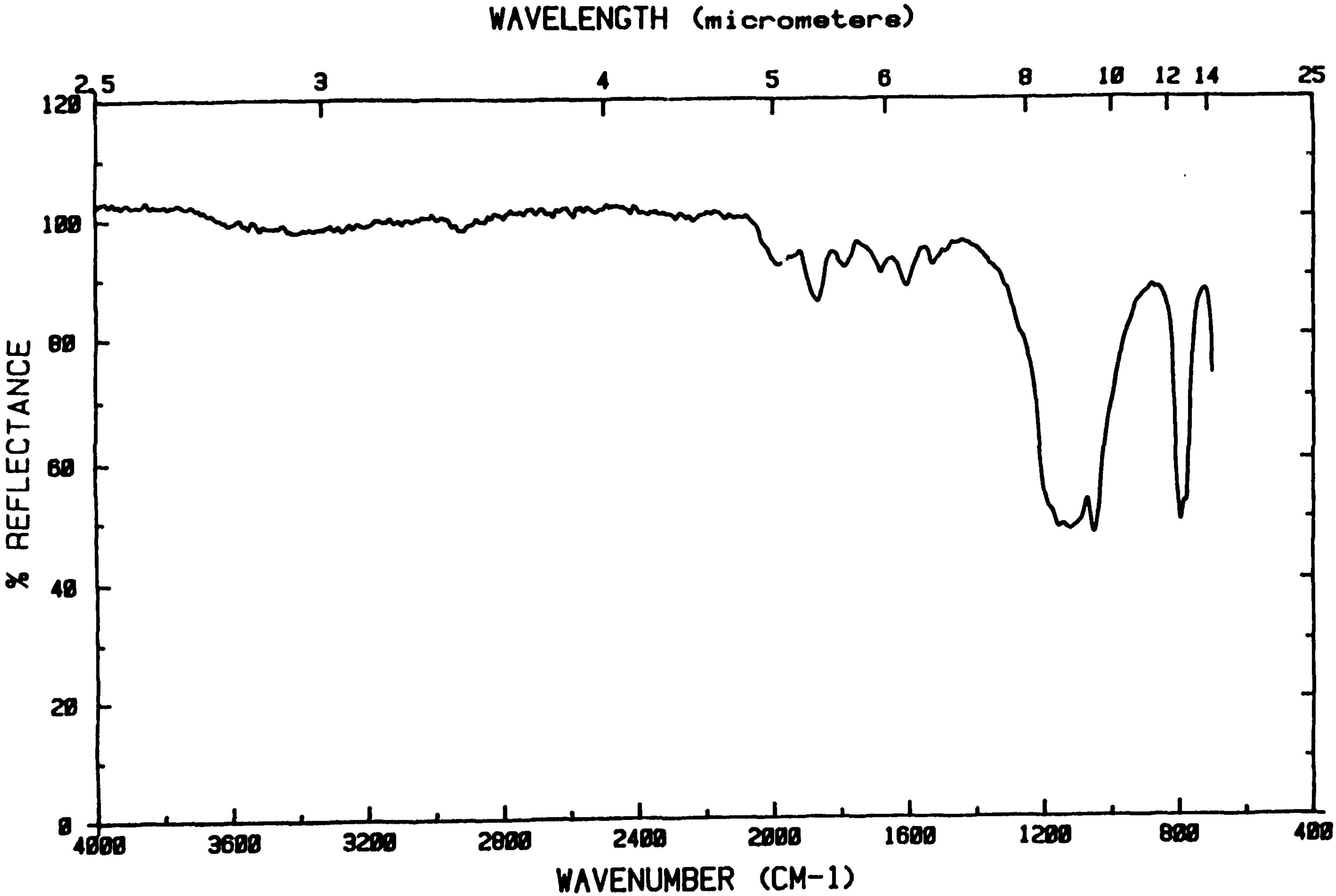
Reference: 600 grit Au coated SiC sandpaper

Sample: Montmorillonite

Origin: Wyoming

Physical state: particulate mineral

Remarks: This is a commercial sample obtained from Ward's Scientific Co.



2% 0-5 UM QUARTZ IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

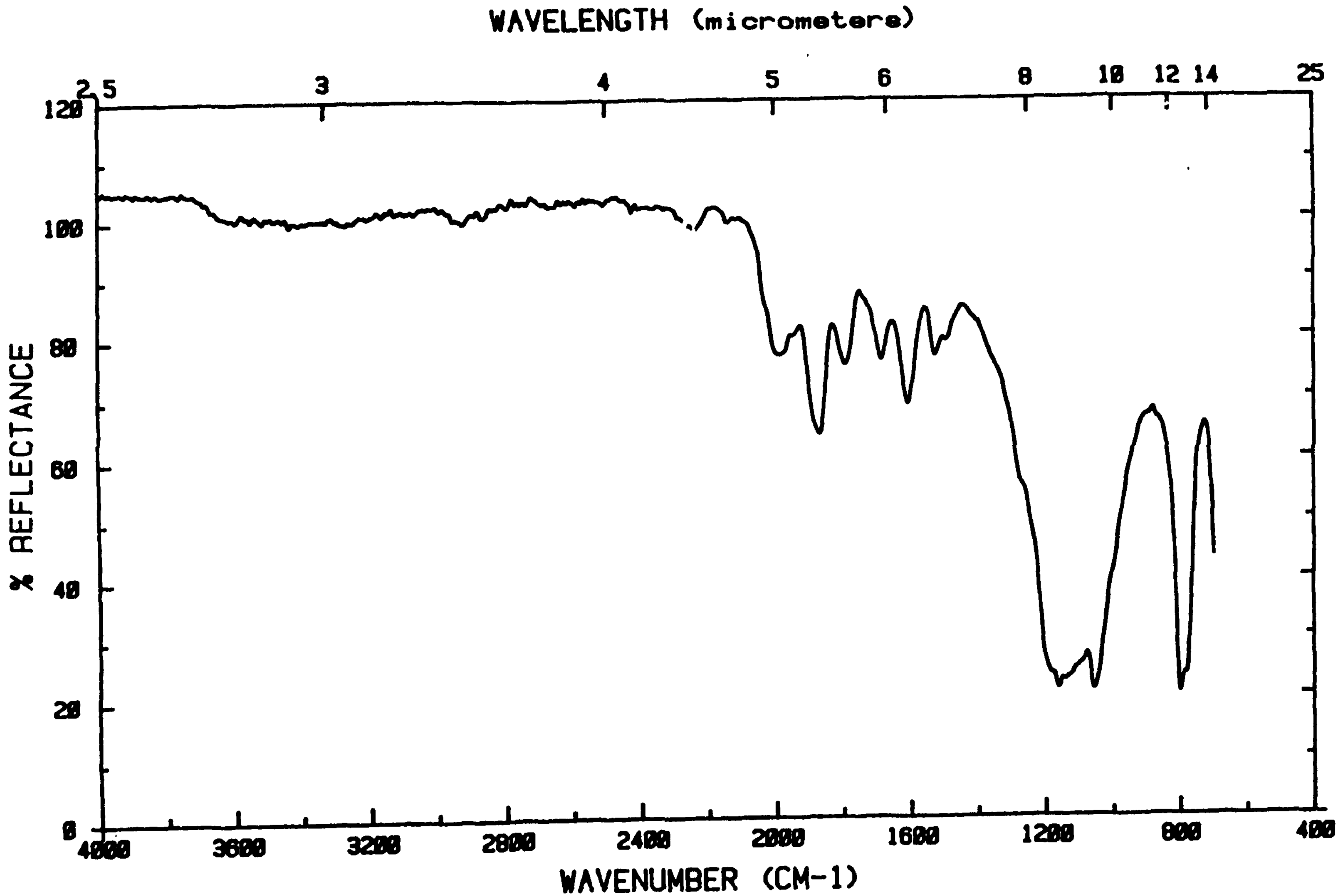
Sample: 2% 0-5 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



10% 0-5 UM QUARTZ IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

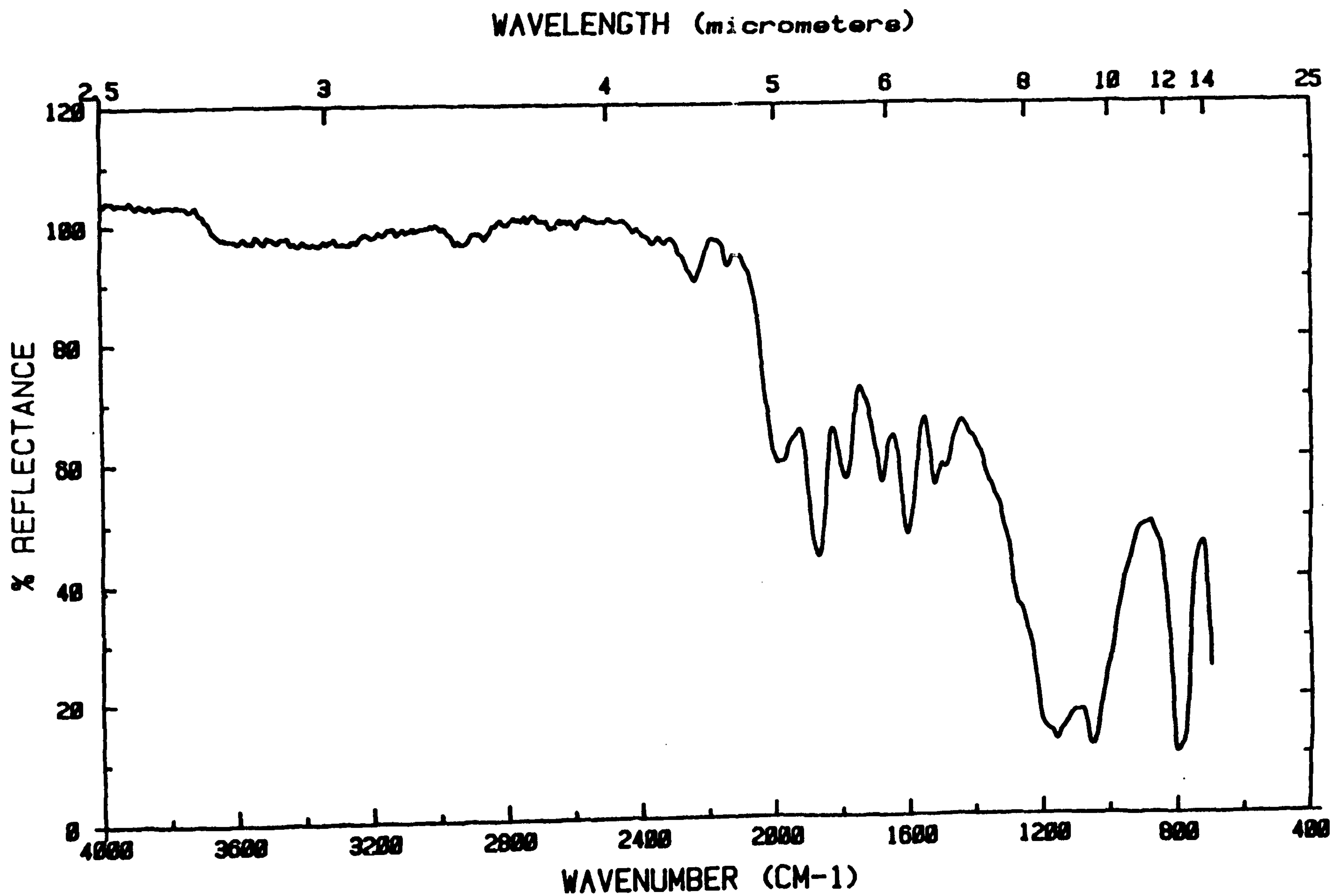
Sample: 10% 0-5 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 0-5 UM QUARTZ IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

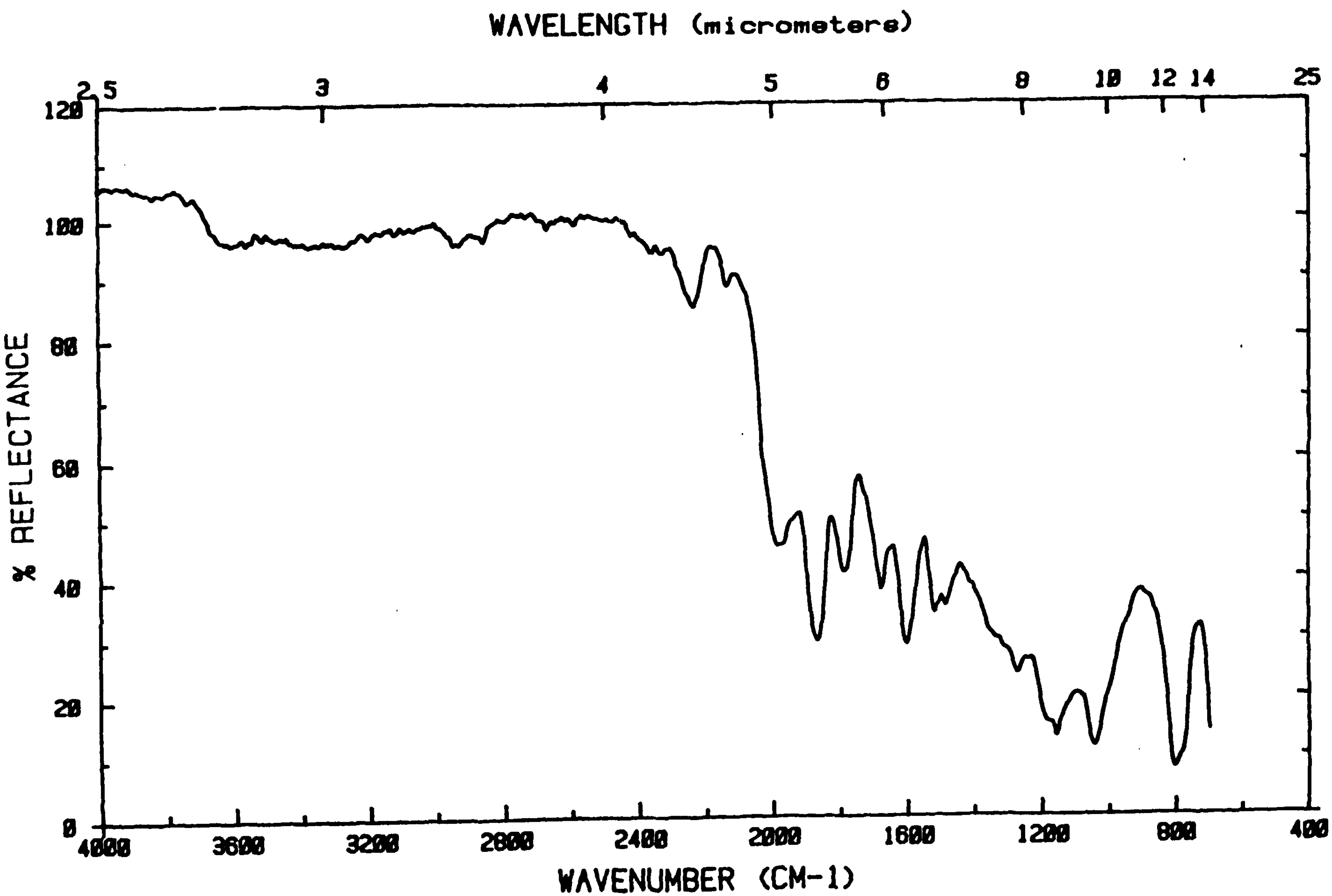
Sample: 25% 0-5 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 0-5 UM QUARTZ IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

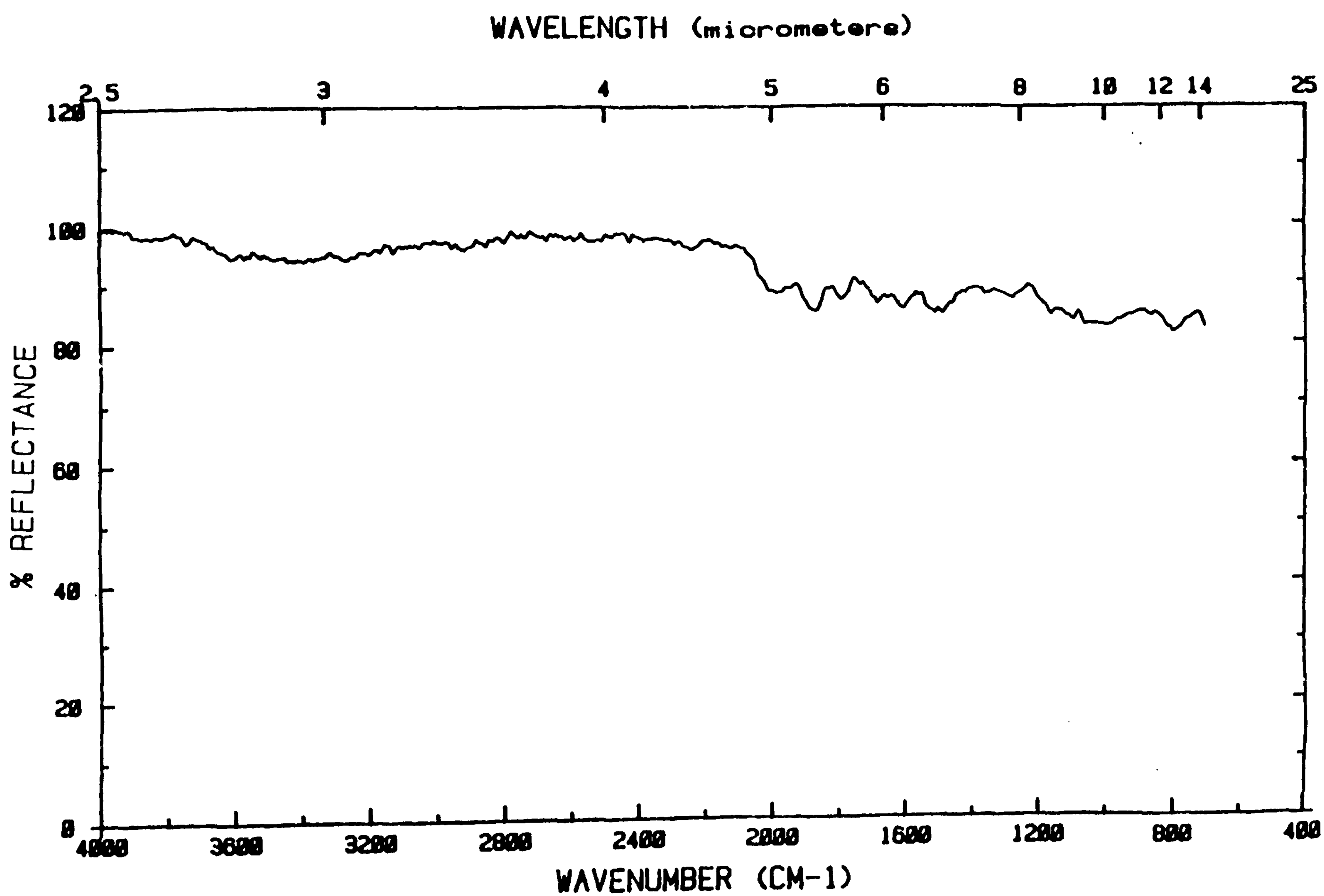
Sample: 50% 0-5 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 0-75 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

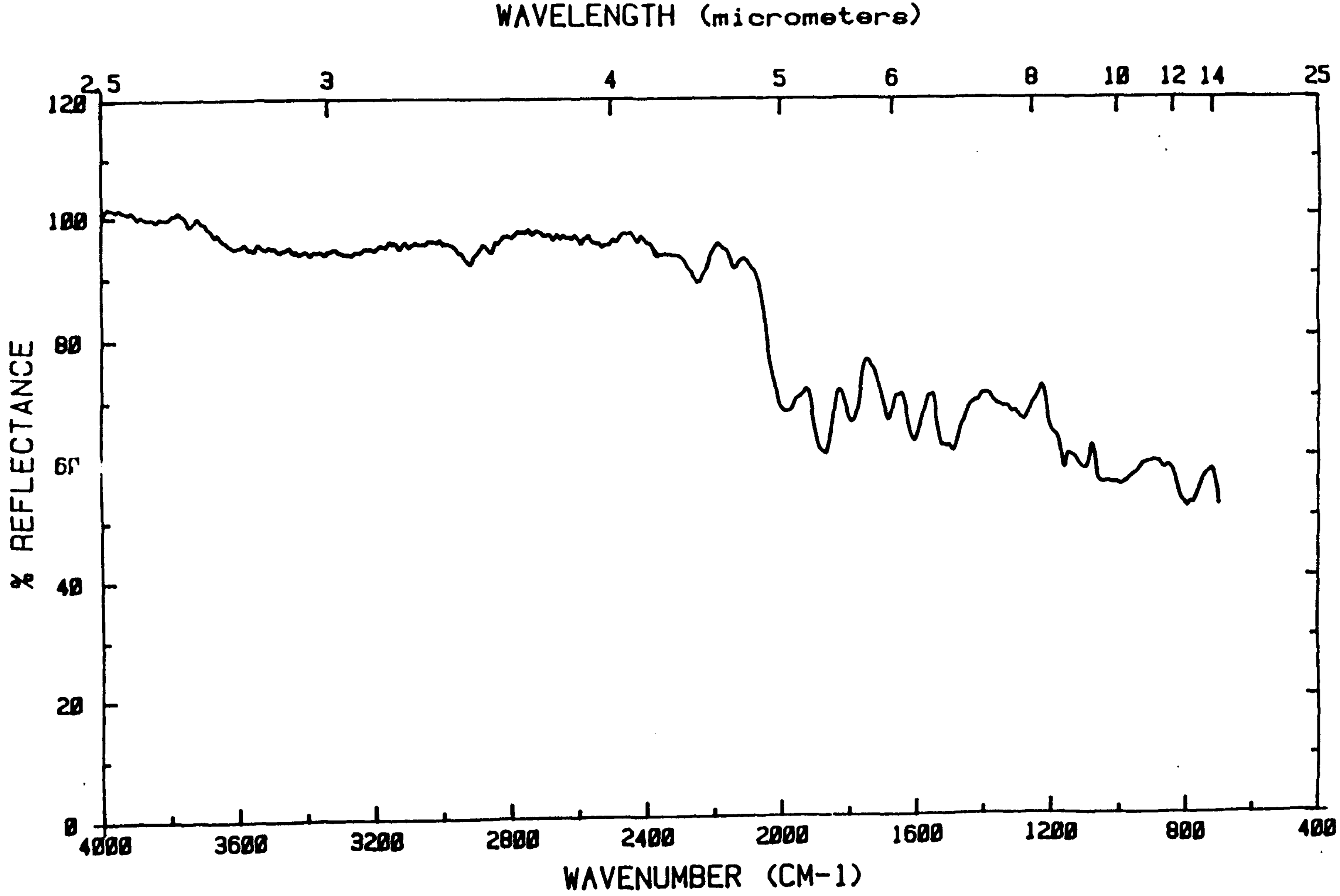
Sample: 2% 0-75 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



15% 0-75 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

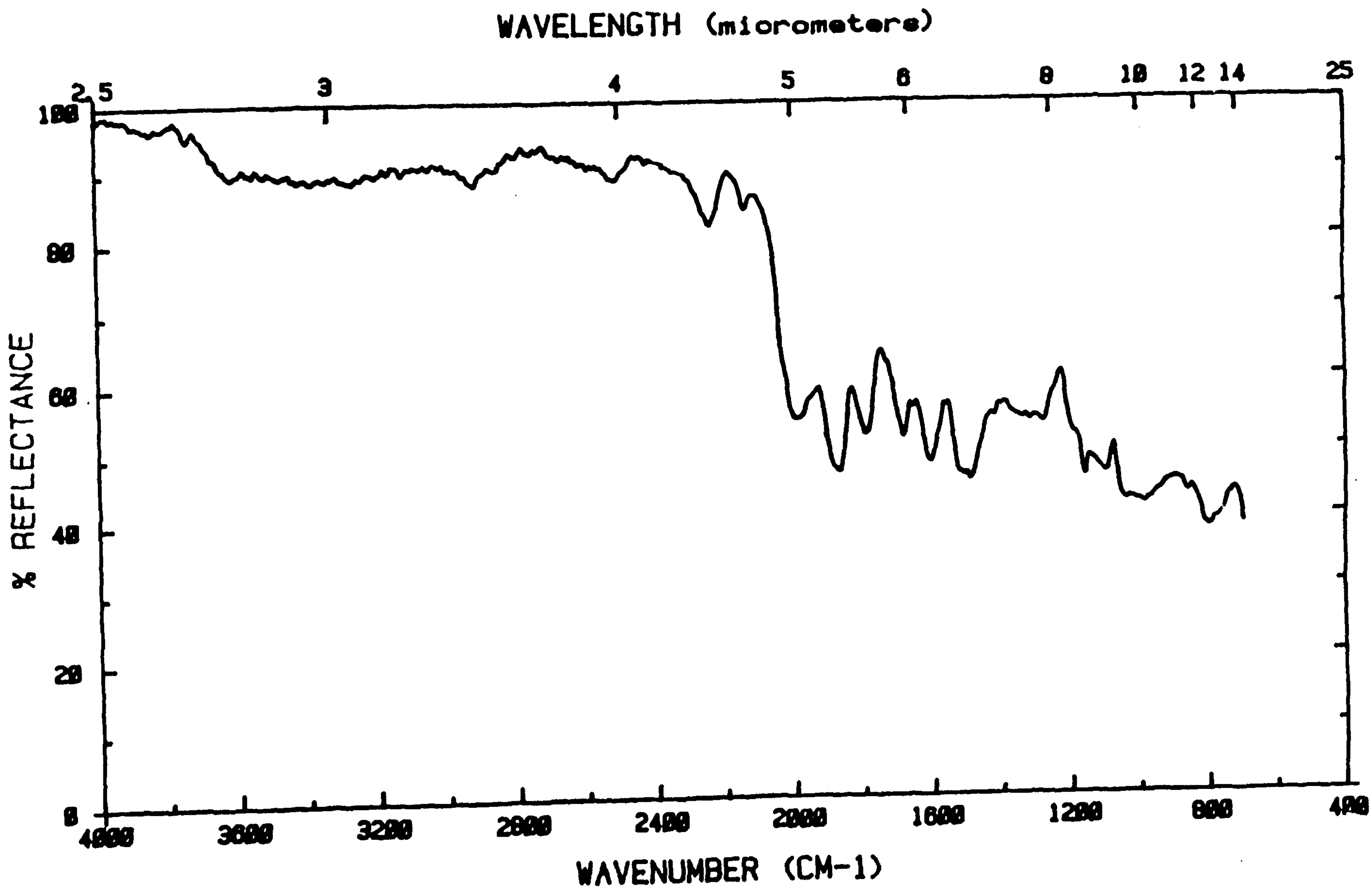
Sample: 15% 0-75 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



25% 0-75 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

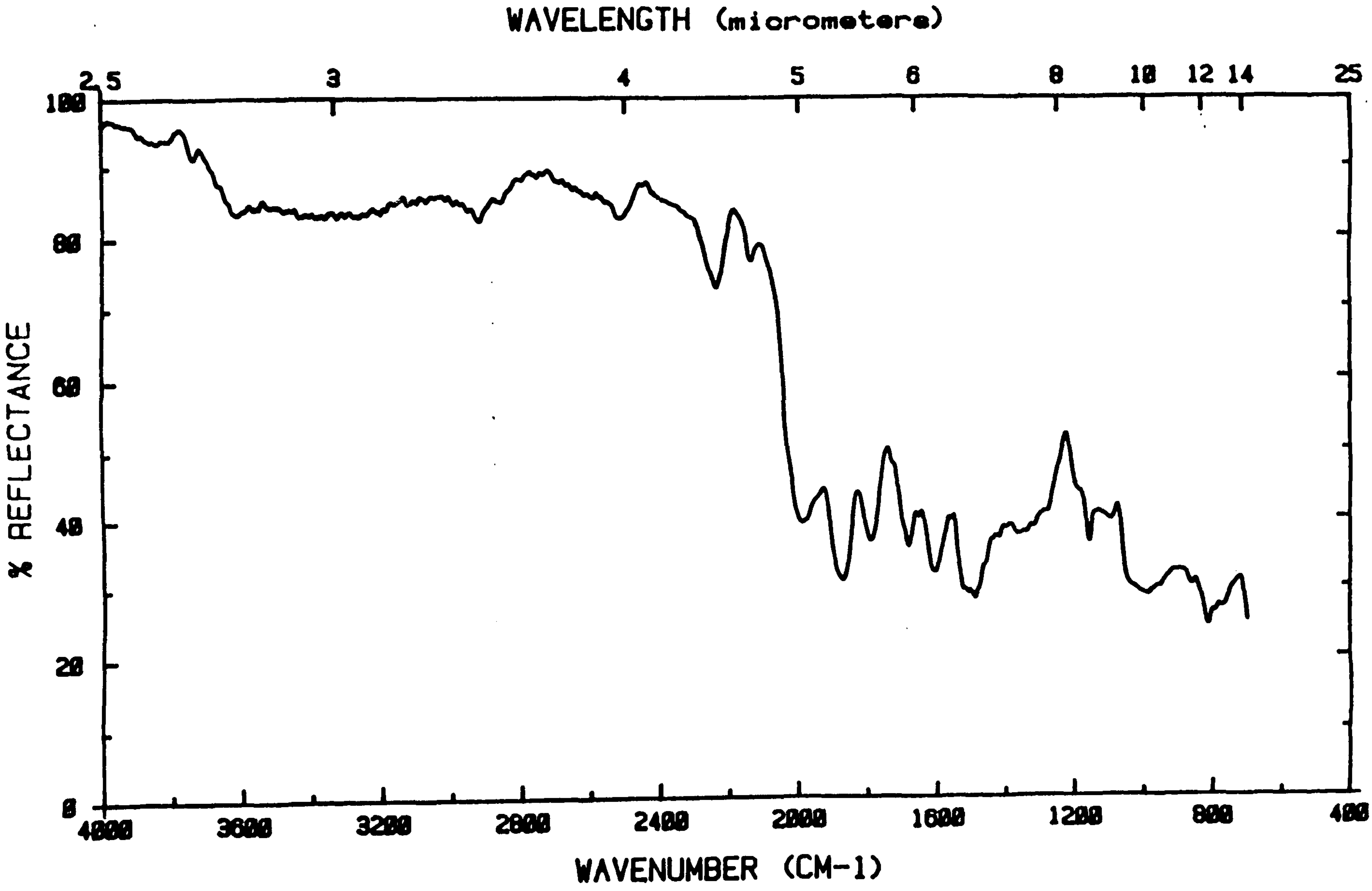
Sample: 25% 0-75 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 0-75 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

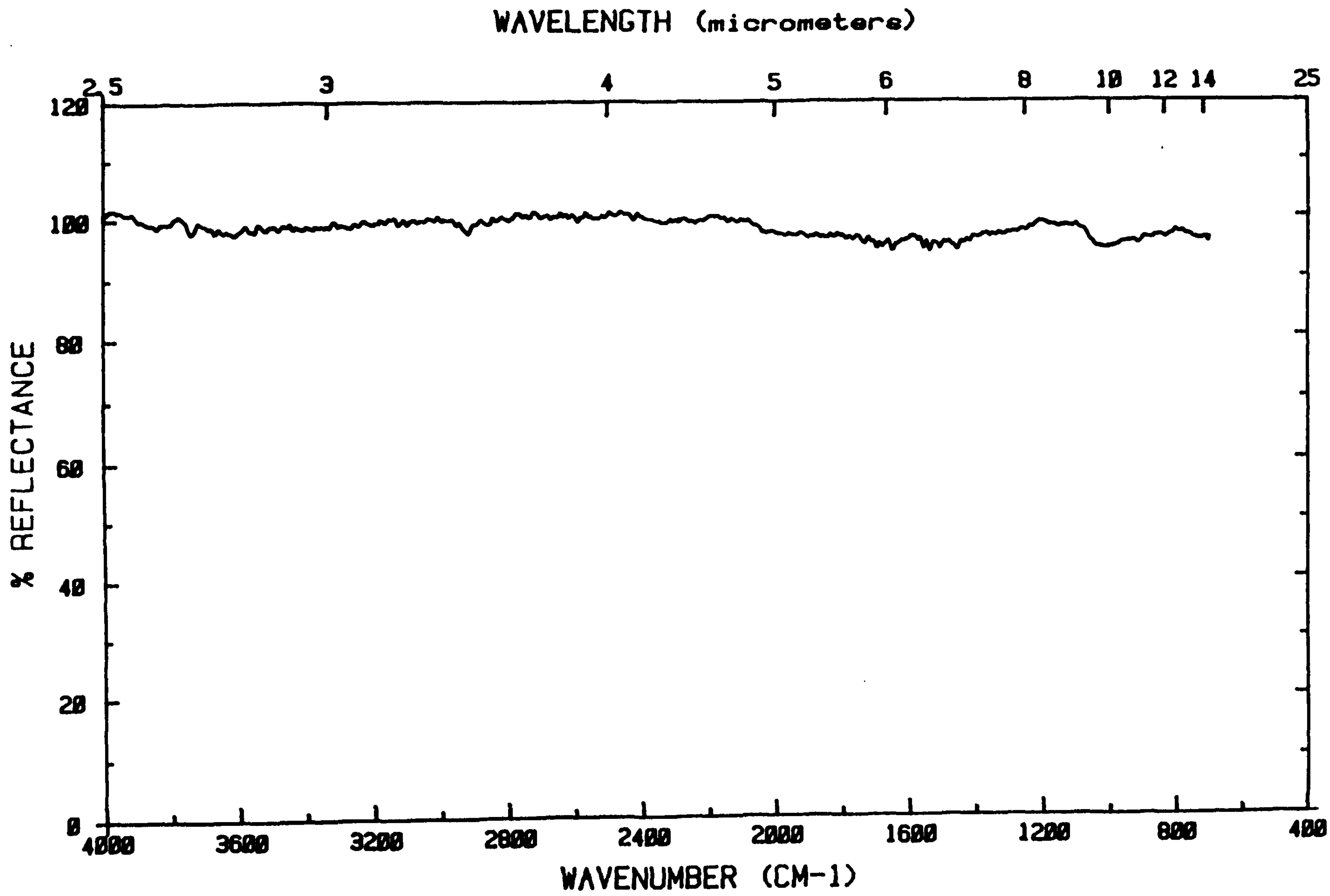
Sample: 50% 0-75 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 75-250 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

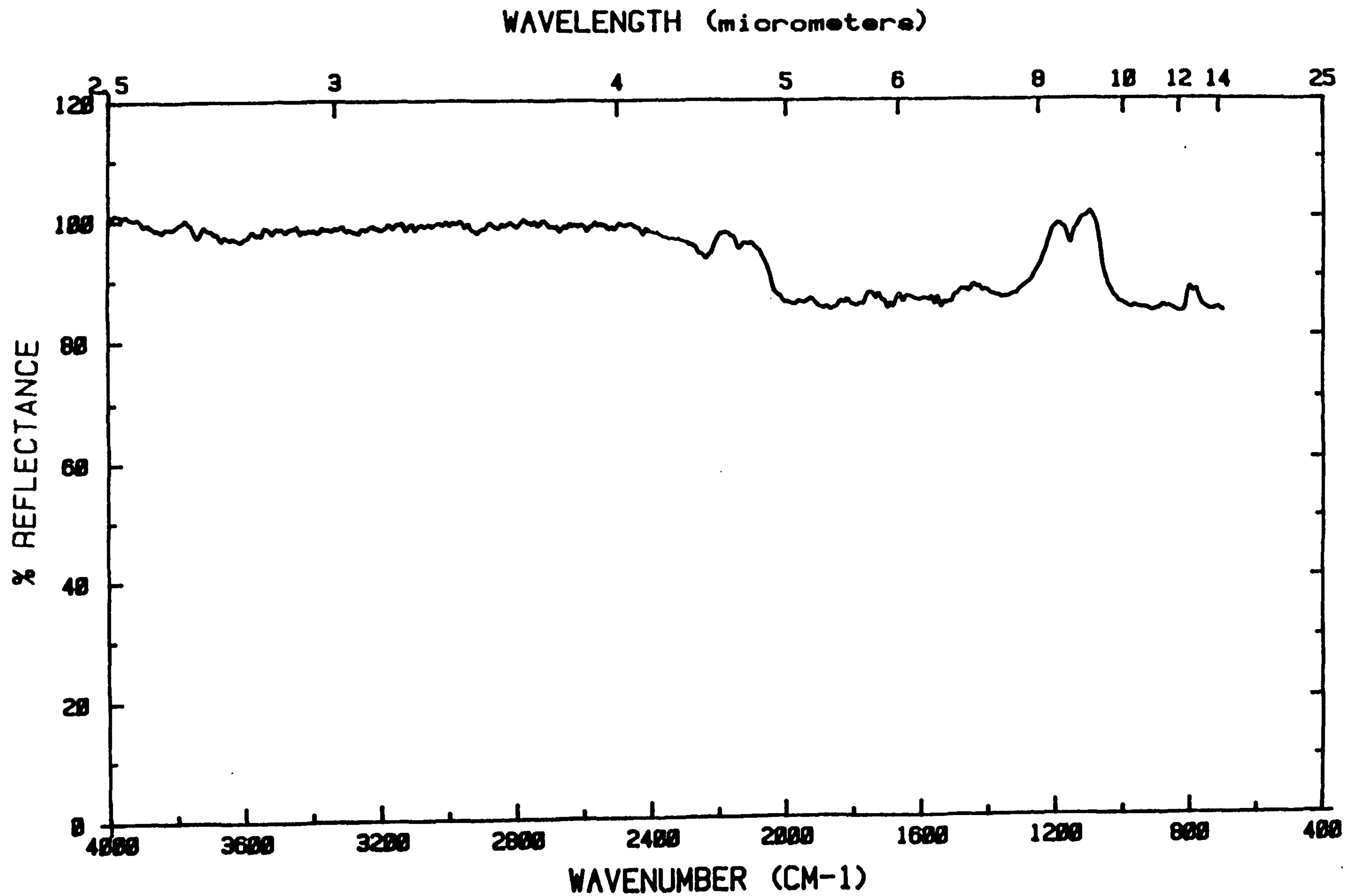
Sample: 2% 75-250 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



10% 75-250 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

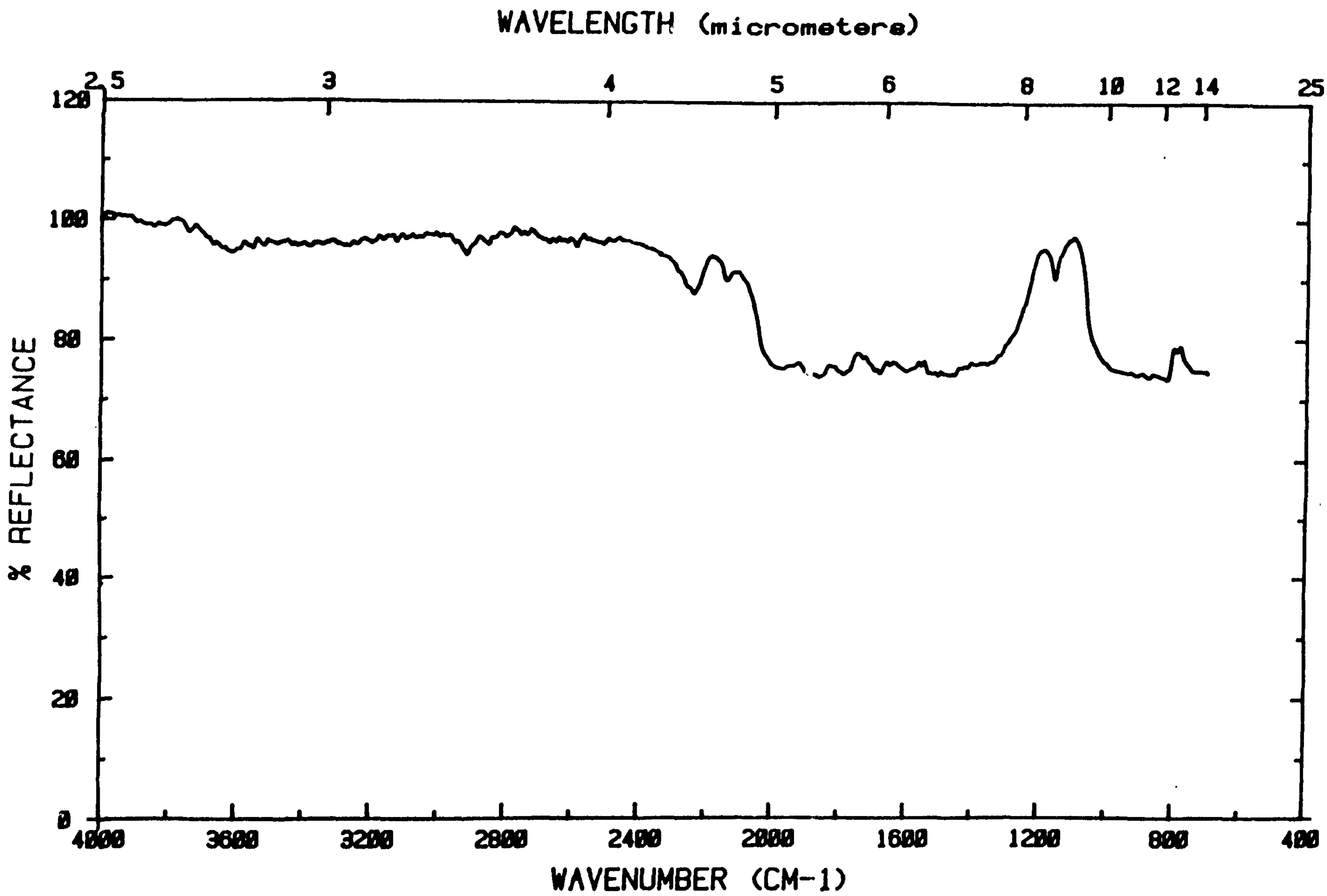
Sample: 10% 75-250 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



15% 75-250 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

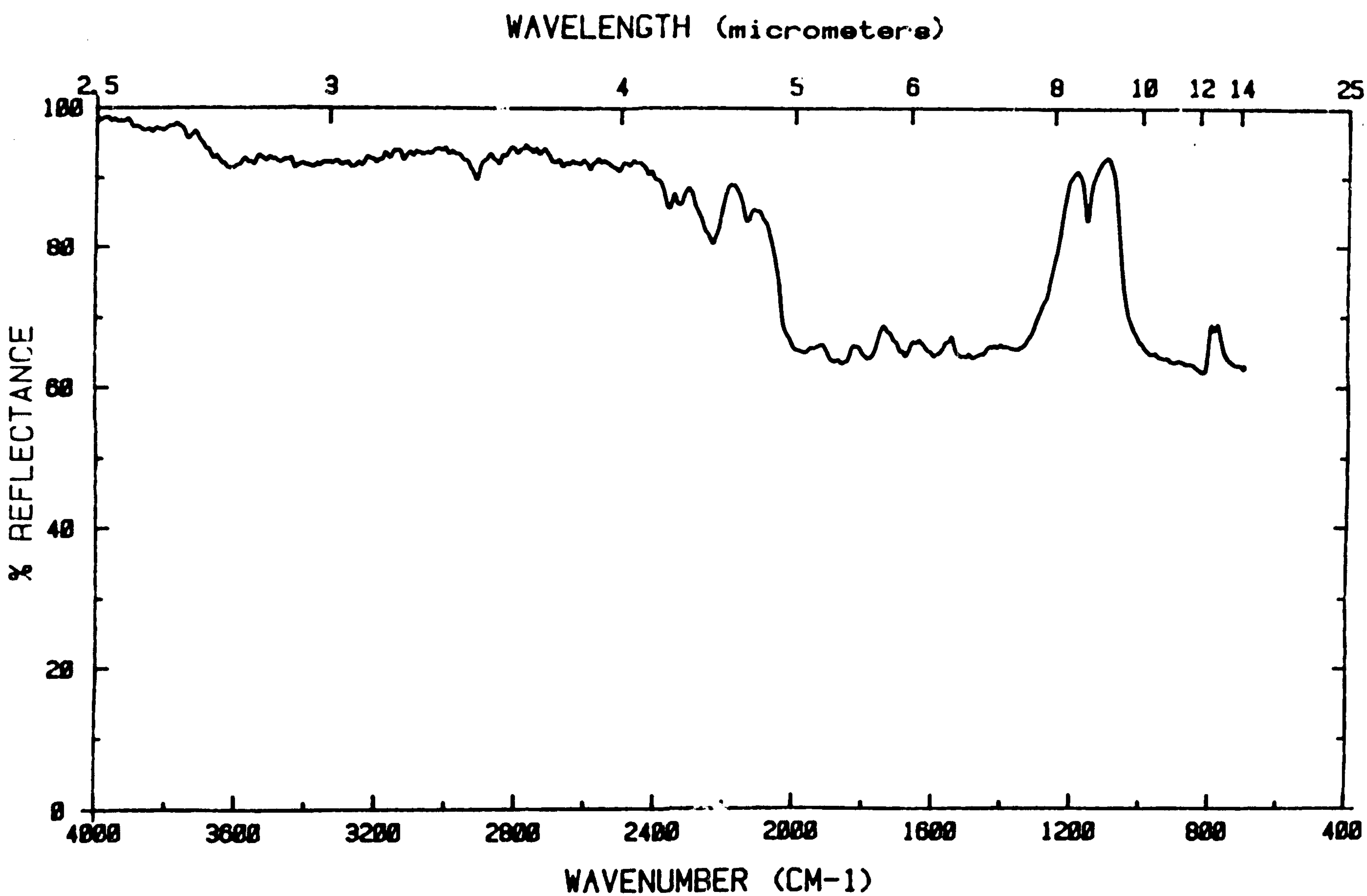
Sample: 15% 75-250 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 75-250 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

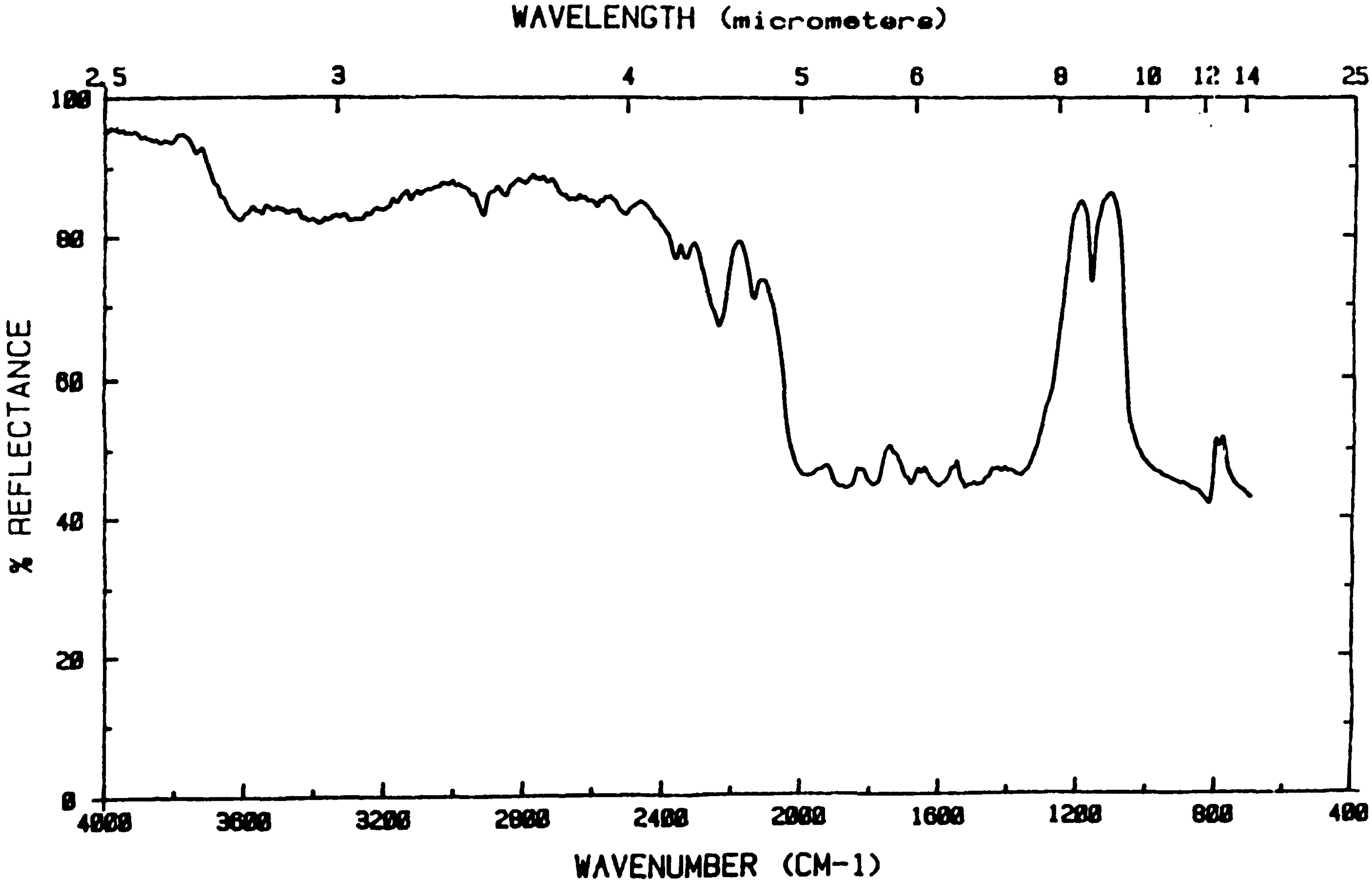
Sample: 25% 75-250 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 75-250 UM QUARTZ SAND IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

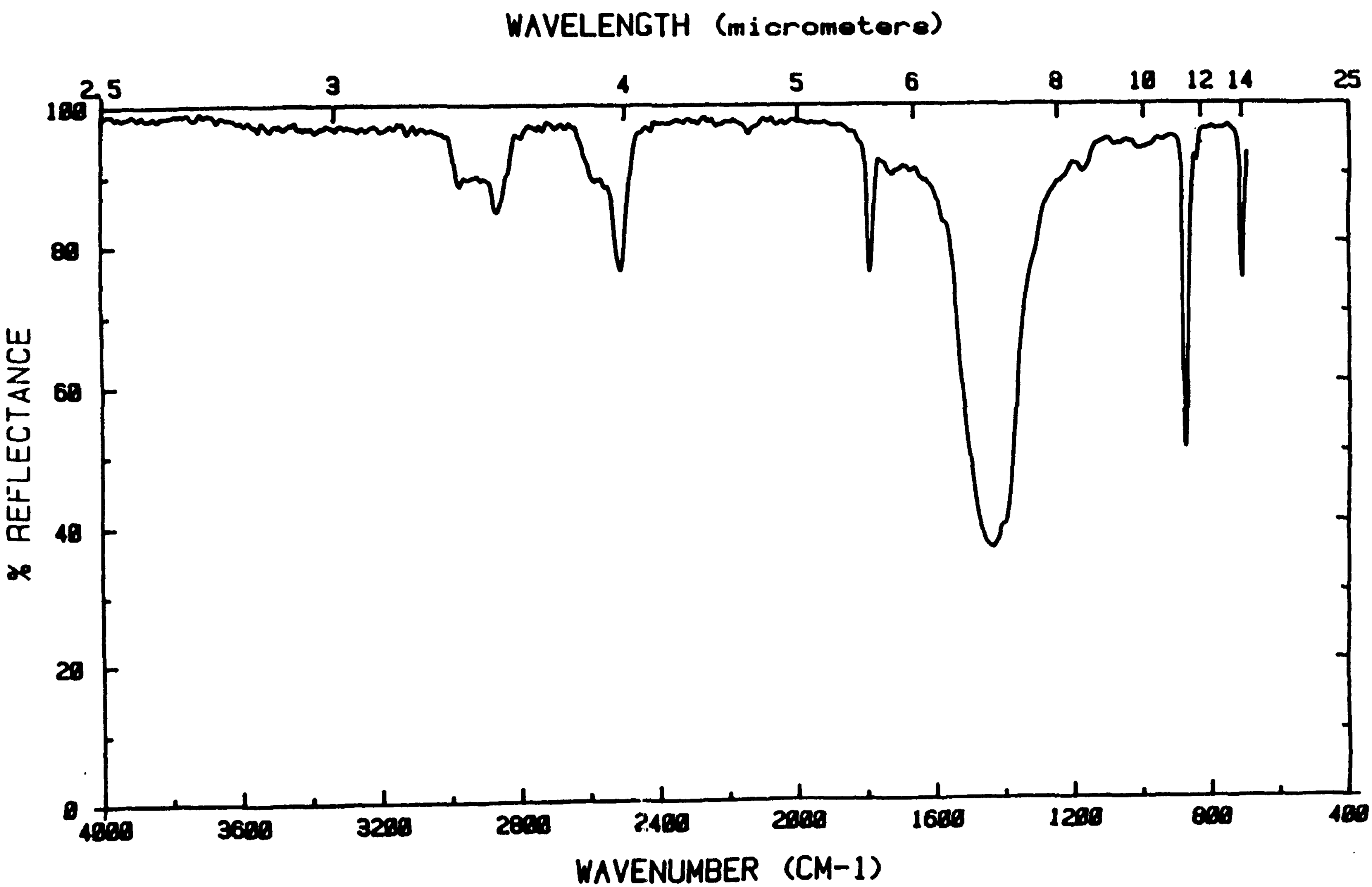
Sample: 50% 75-250 micrometer quartz in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 0-5 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

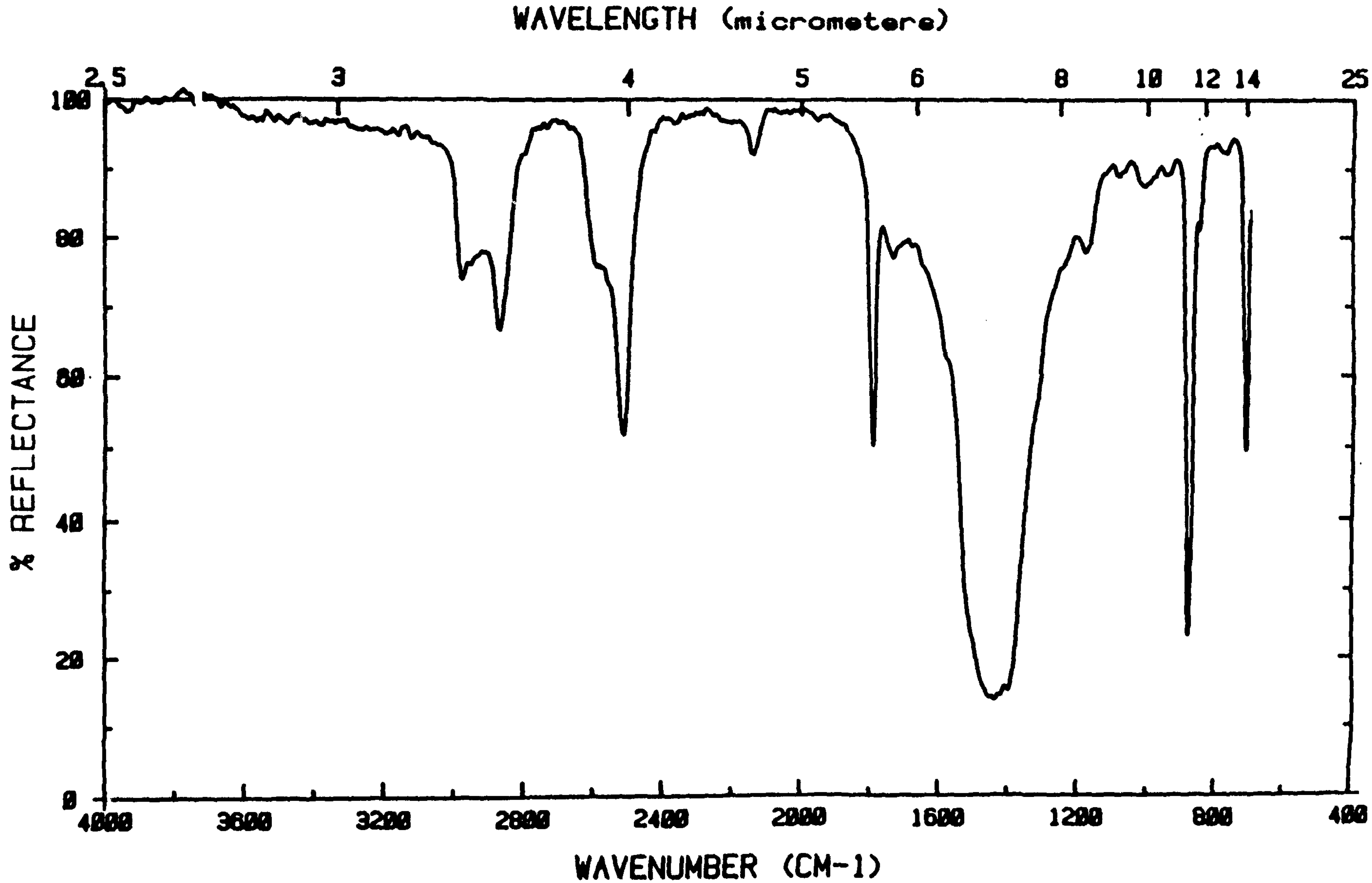
Sample: 2% 0-5 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



10% 0-5 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

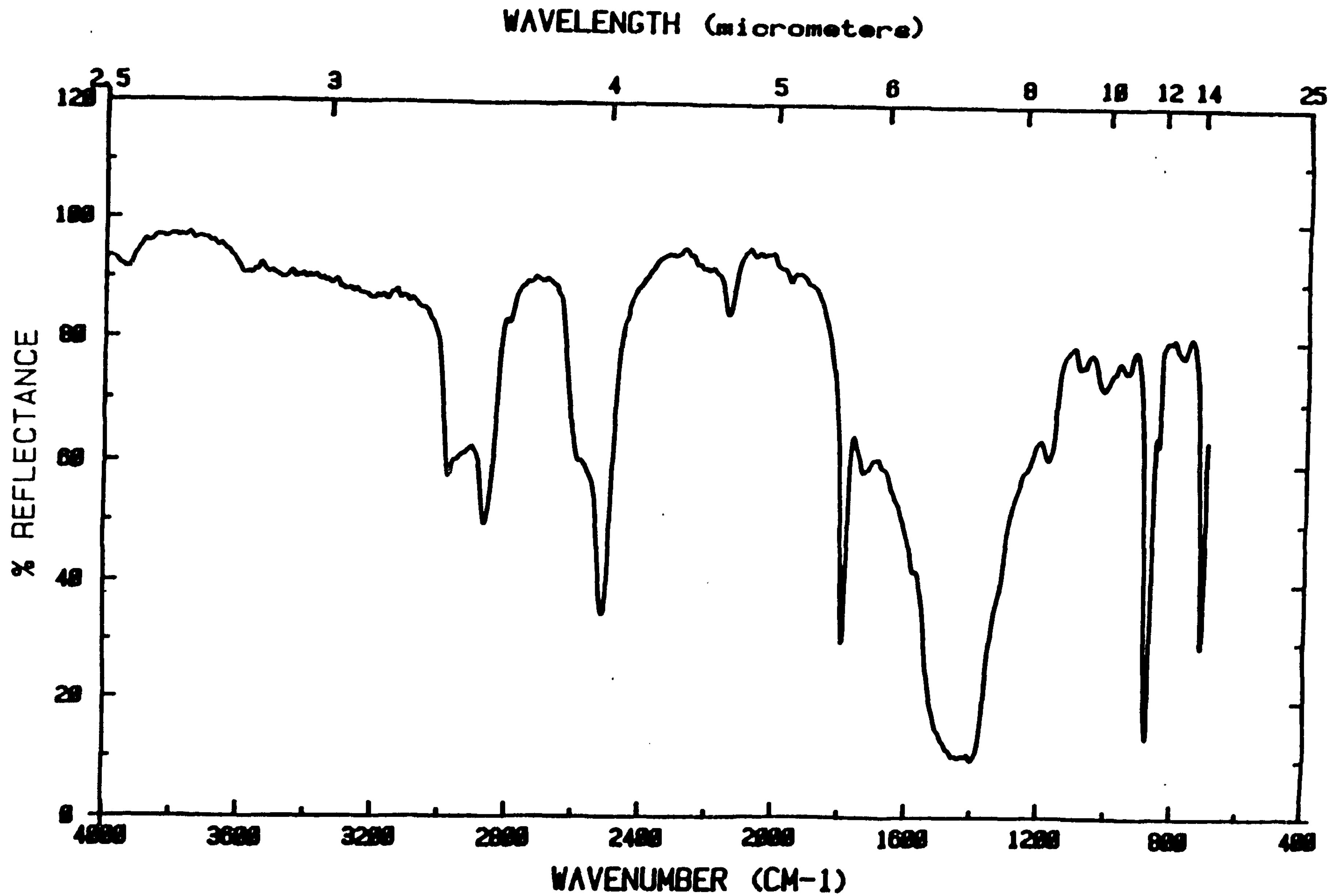
Sample: 10% 0-5 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 0-5 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

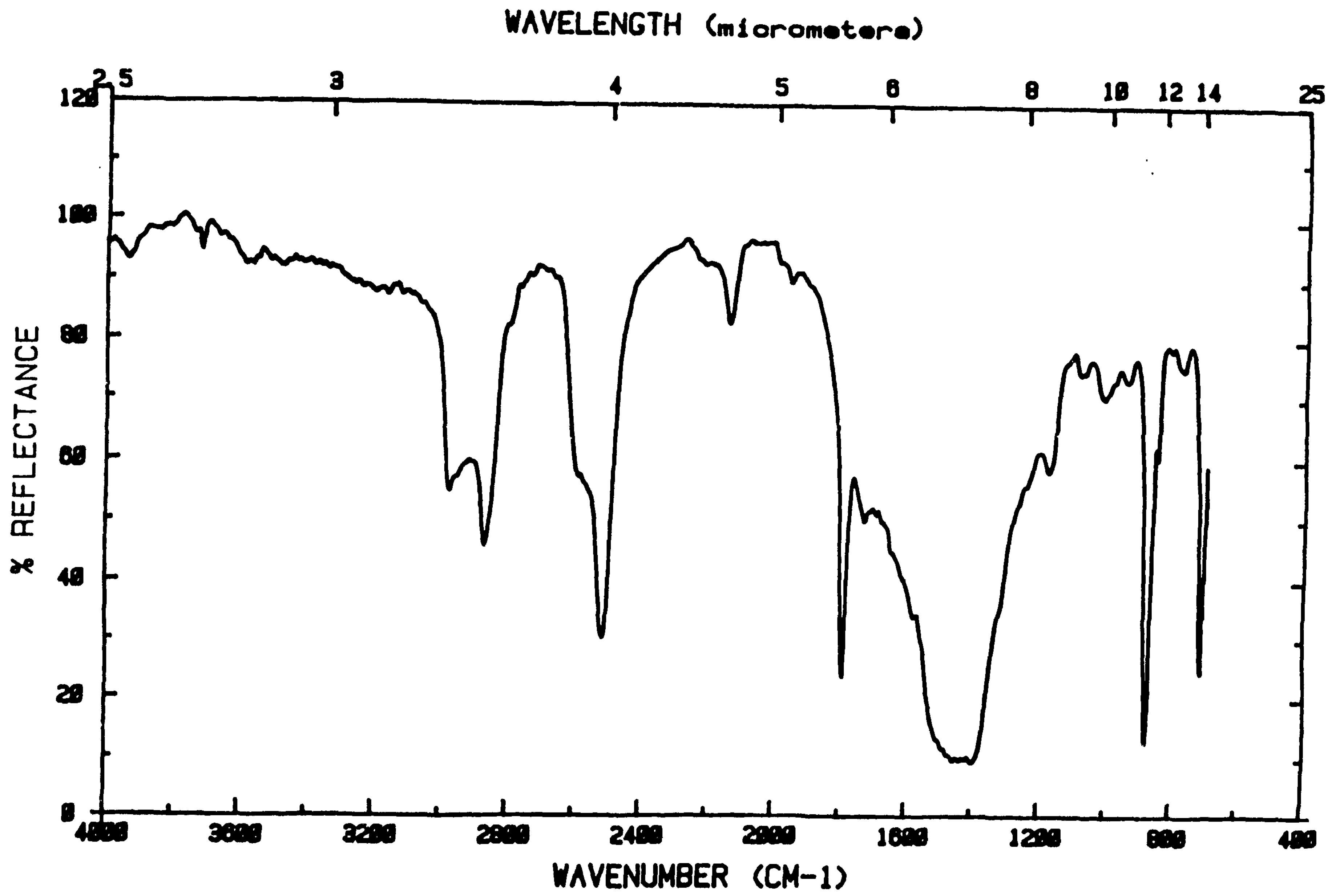
Sample: 25% 0-5 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 0-5 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

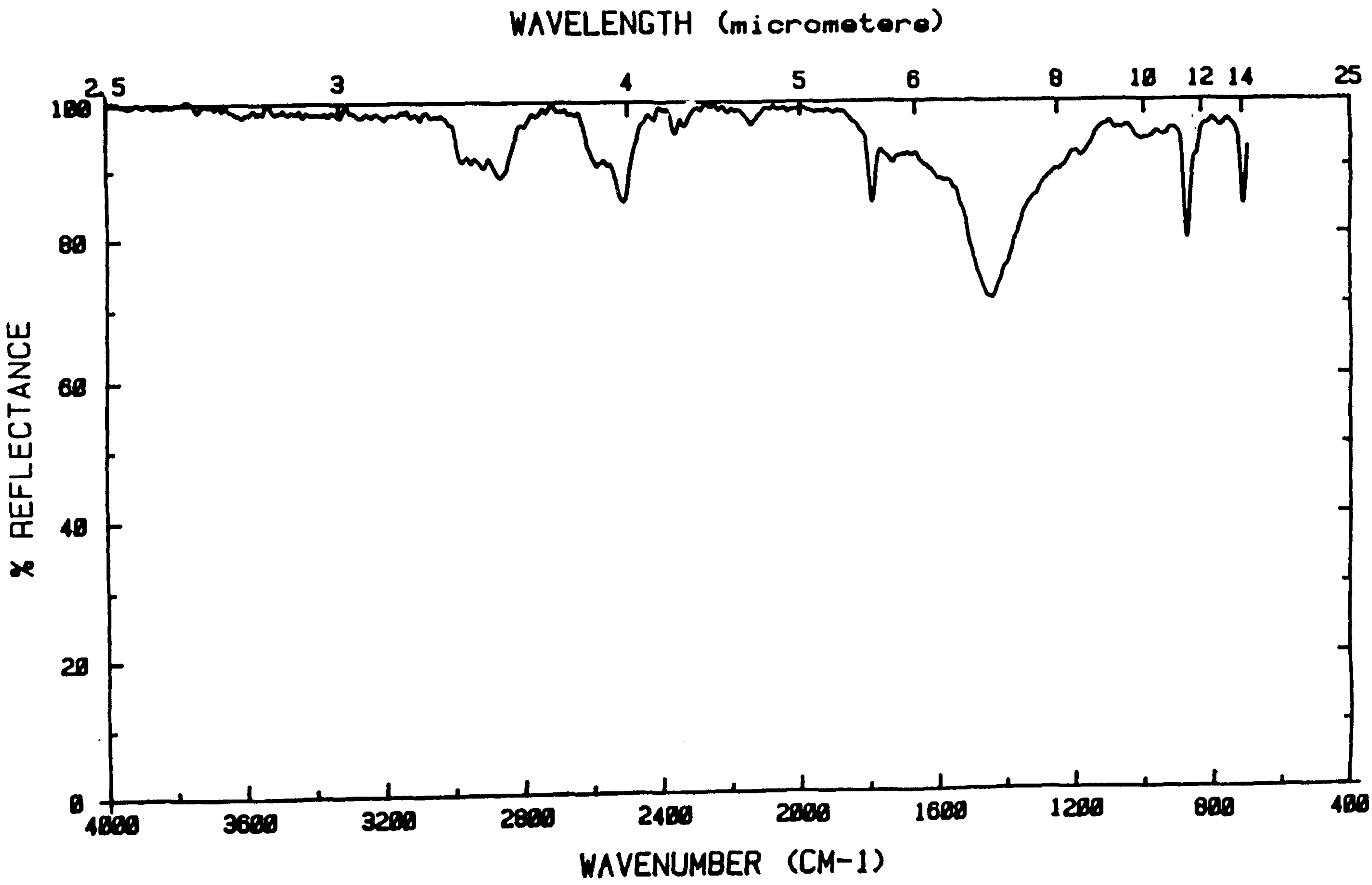
Sample: 50% 0-5 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 0-74 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

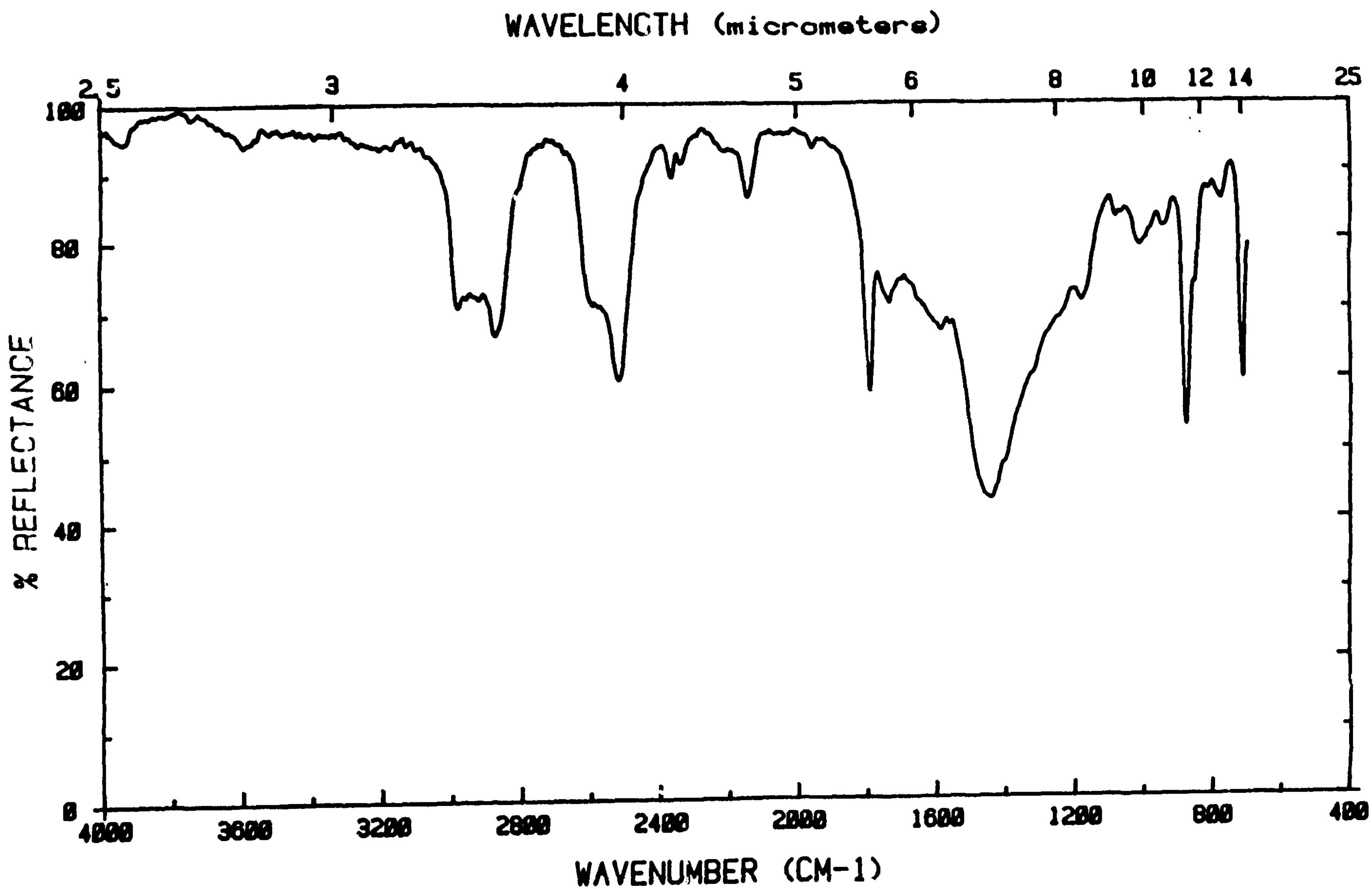
Sample: 2% 0-74 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



10[illegible] 0-74 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

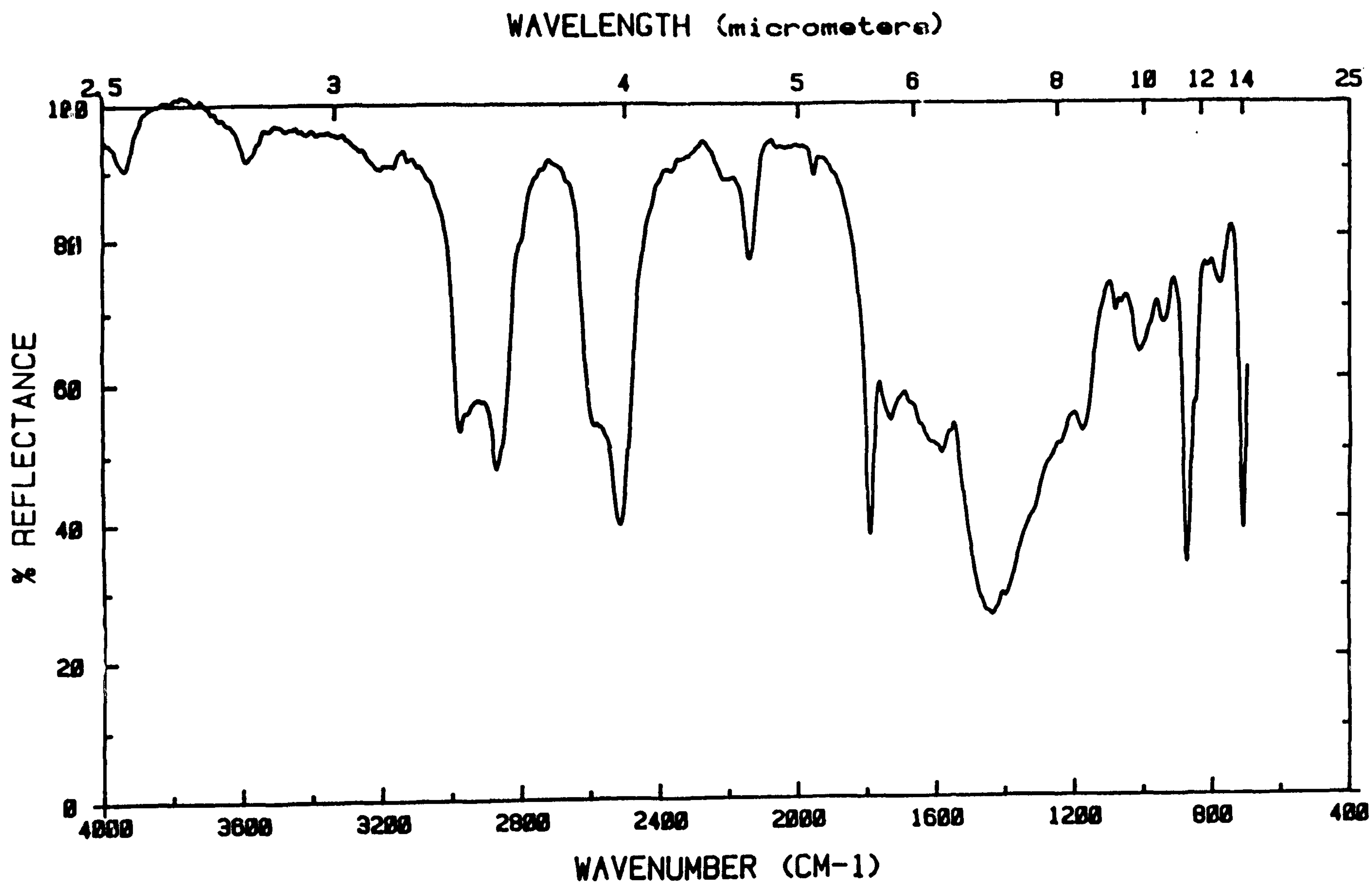
Sample: 10% 0-74 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 0-74 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

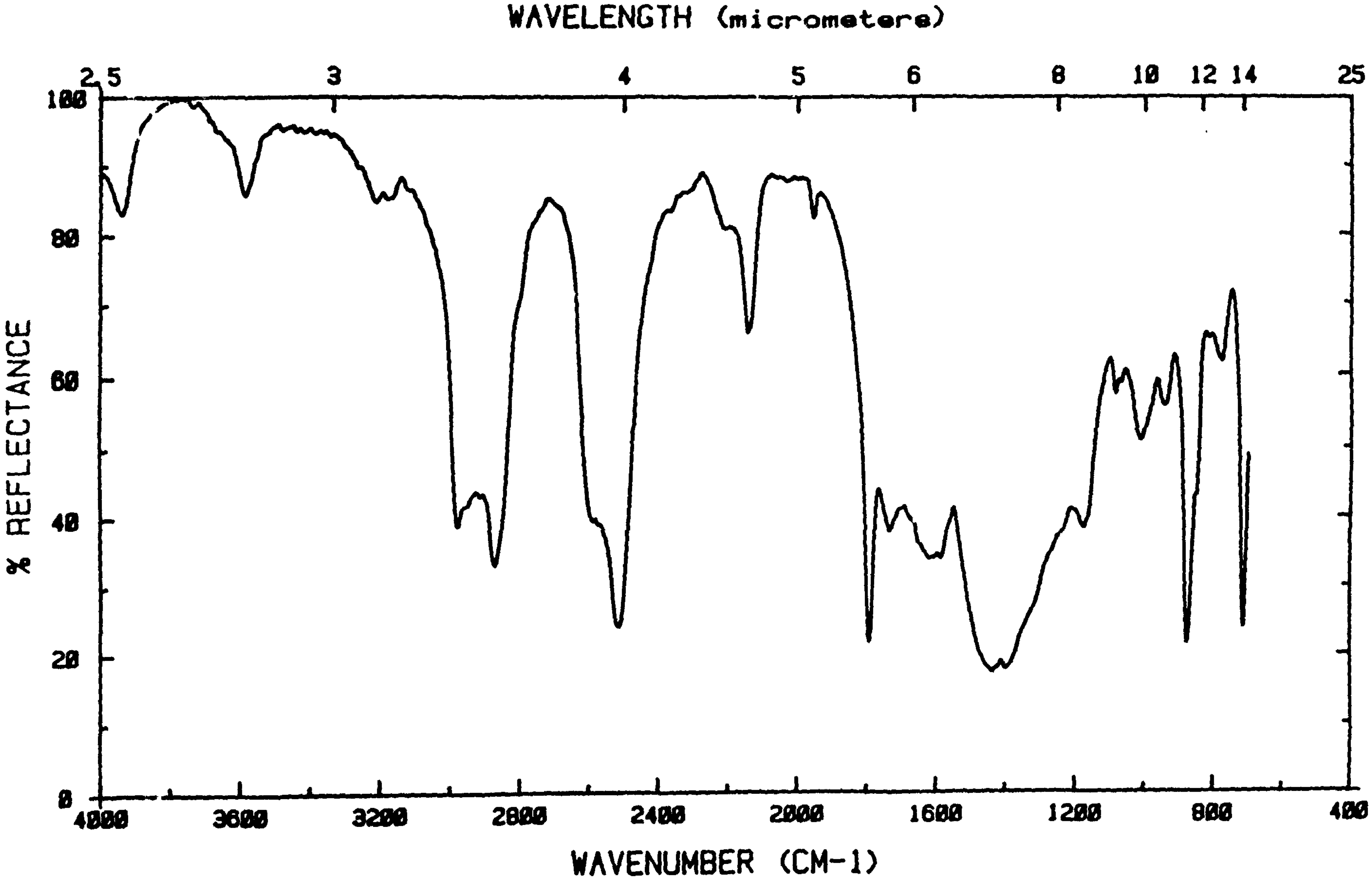
Sample: 25% 0-74 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 0-74 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

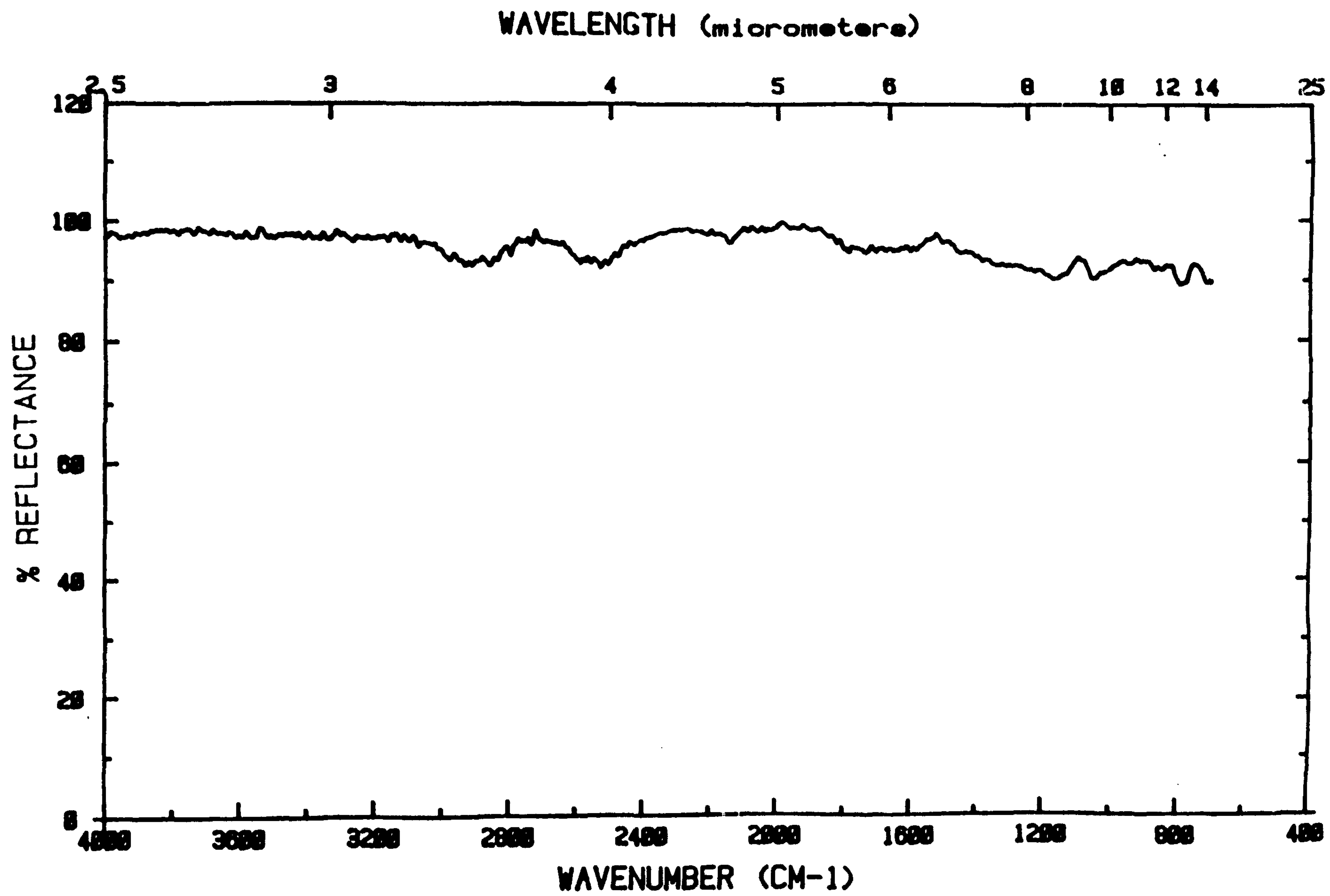
Sample: 50% 0-74 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 74-250 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

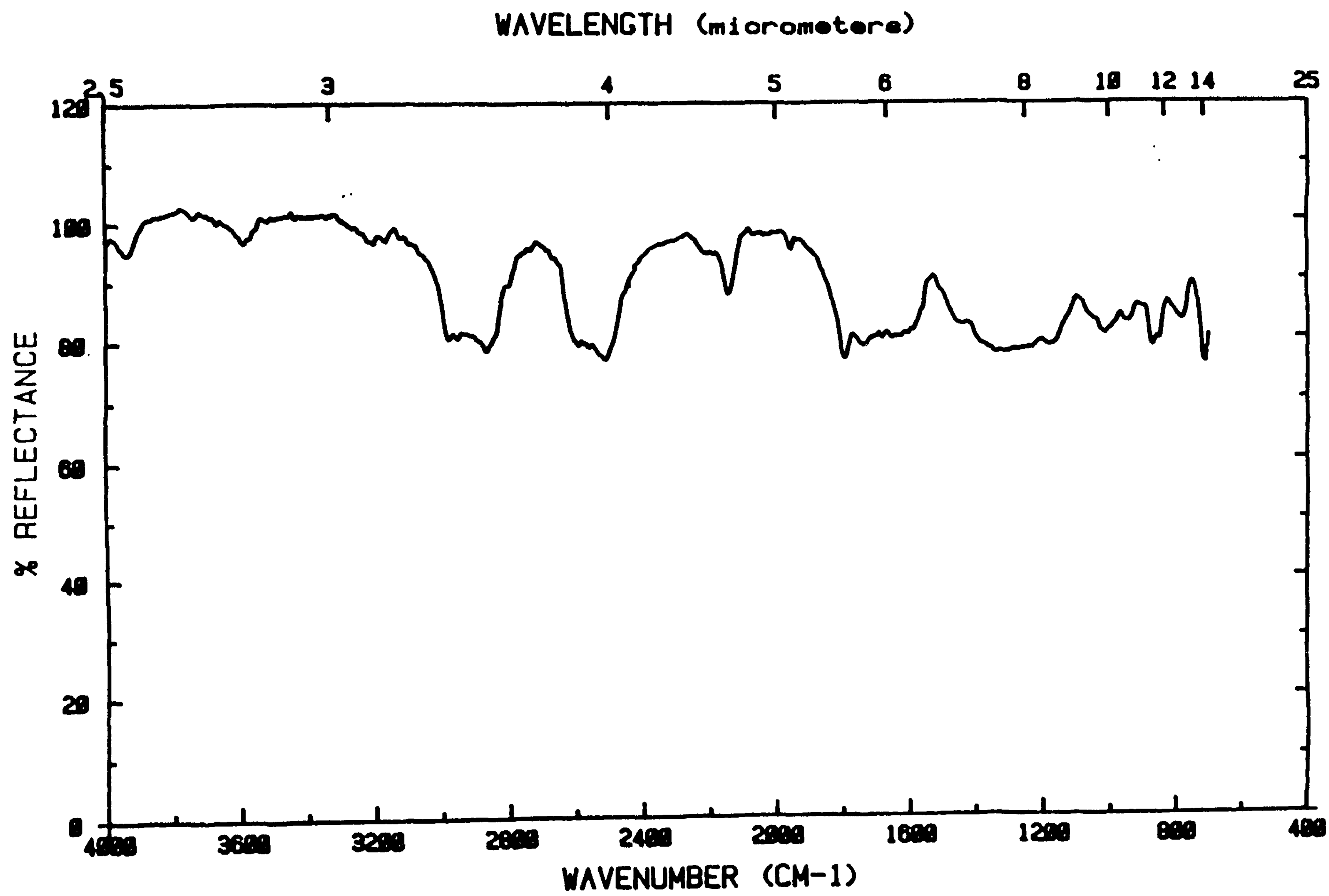
Sample: 20% 74-250 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



10% 74-250 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

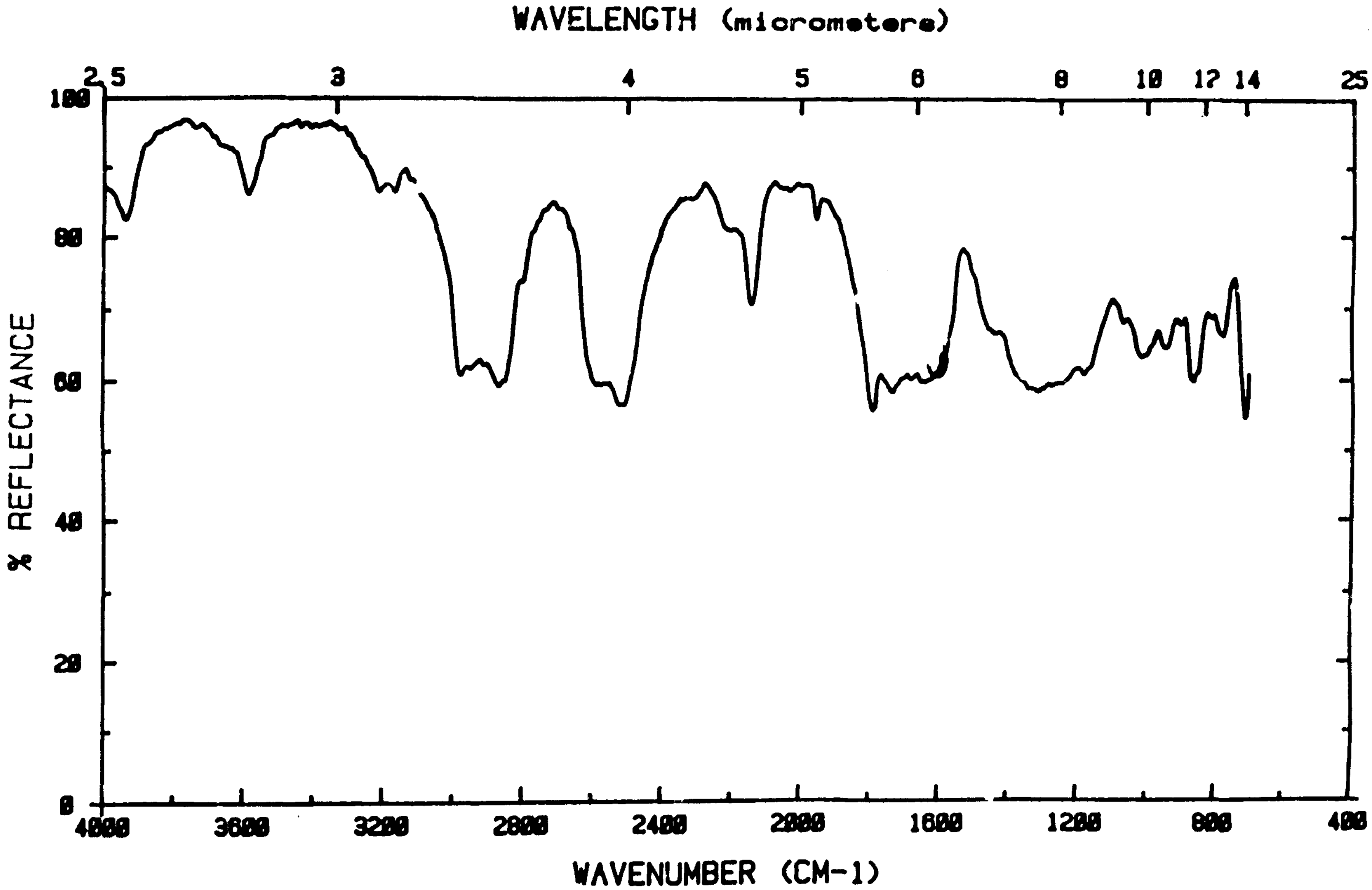
Sample: 10% 74-250 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 74-250 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

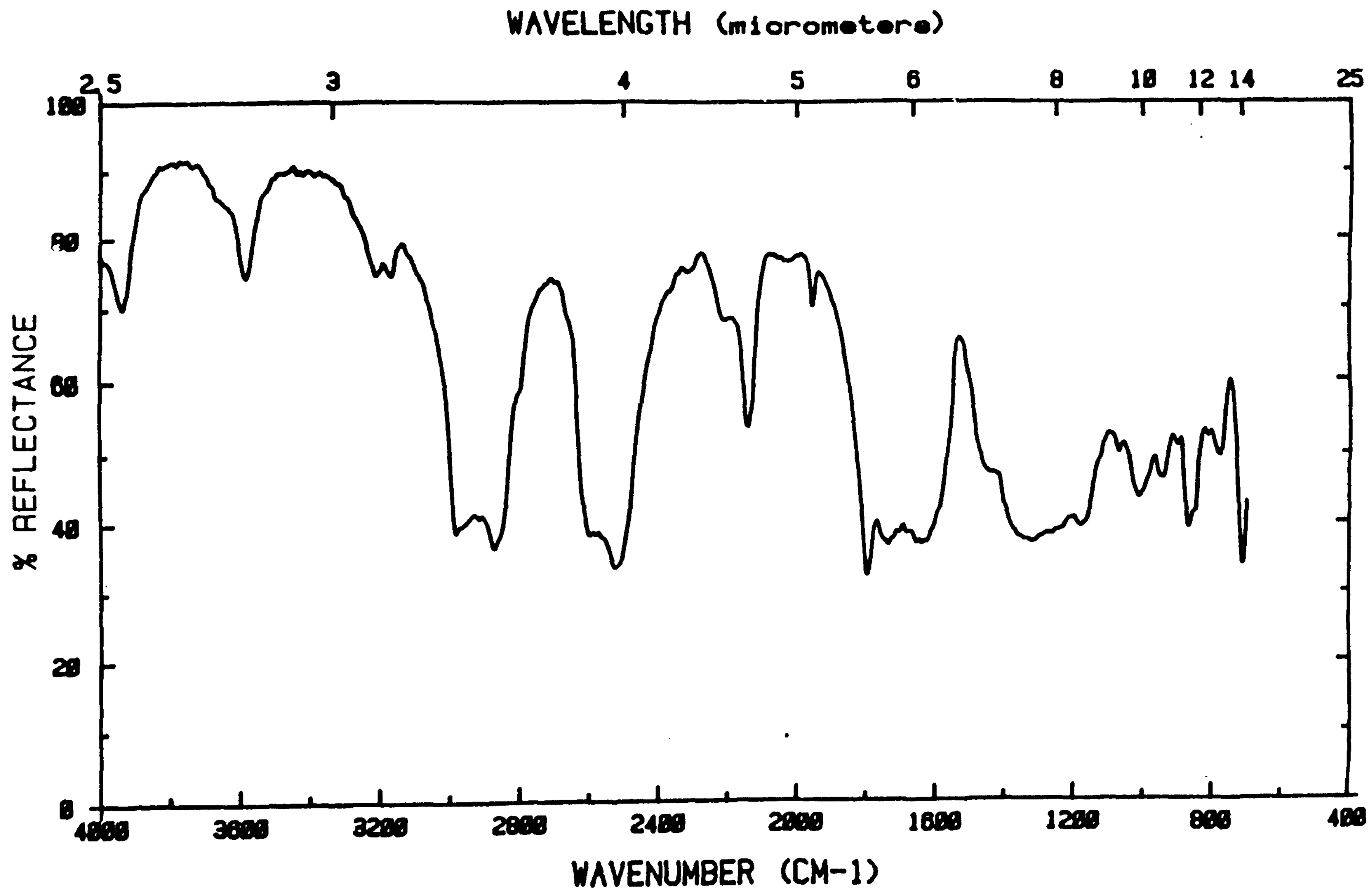
Sample: 25% 74-250 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 74-250 UM CALCITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

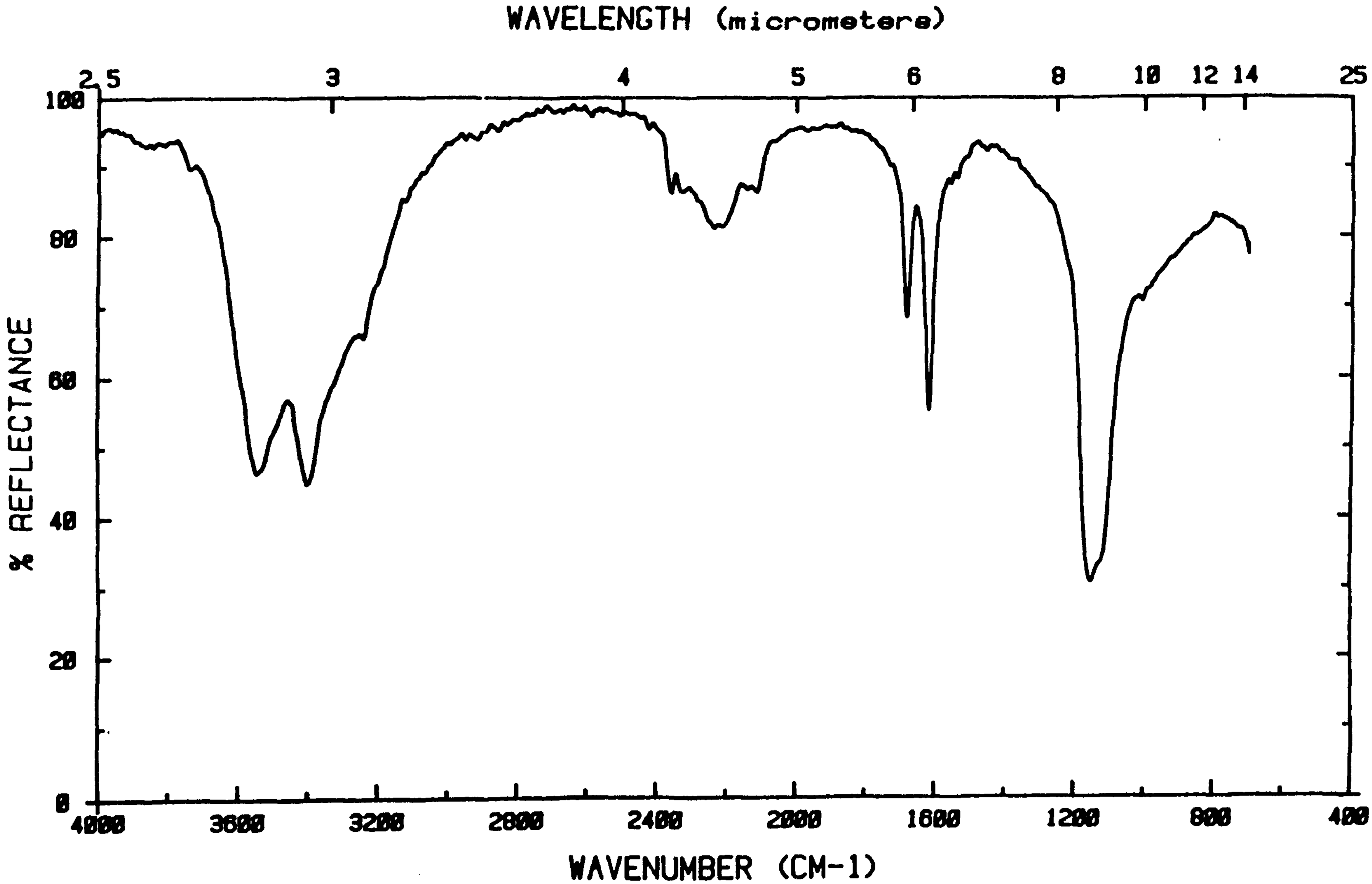
Sample: 50% 74-250 micrometer calcite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 0-5 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

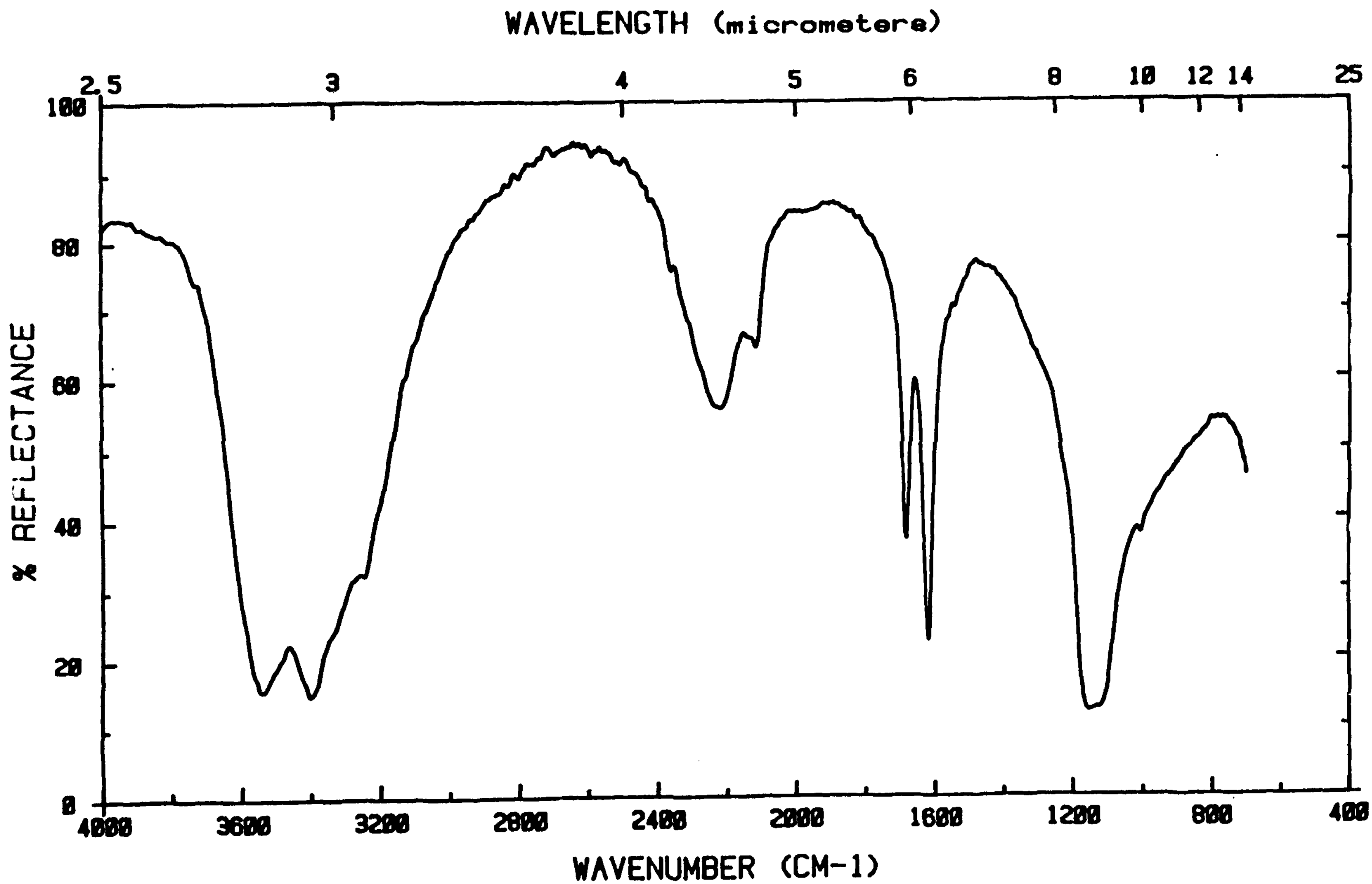
Sample: 2% 0-5 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



10% 0-5 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

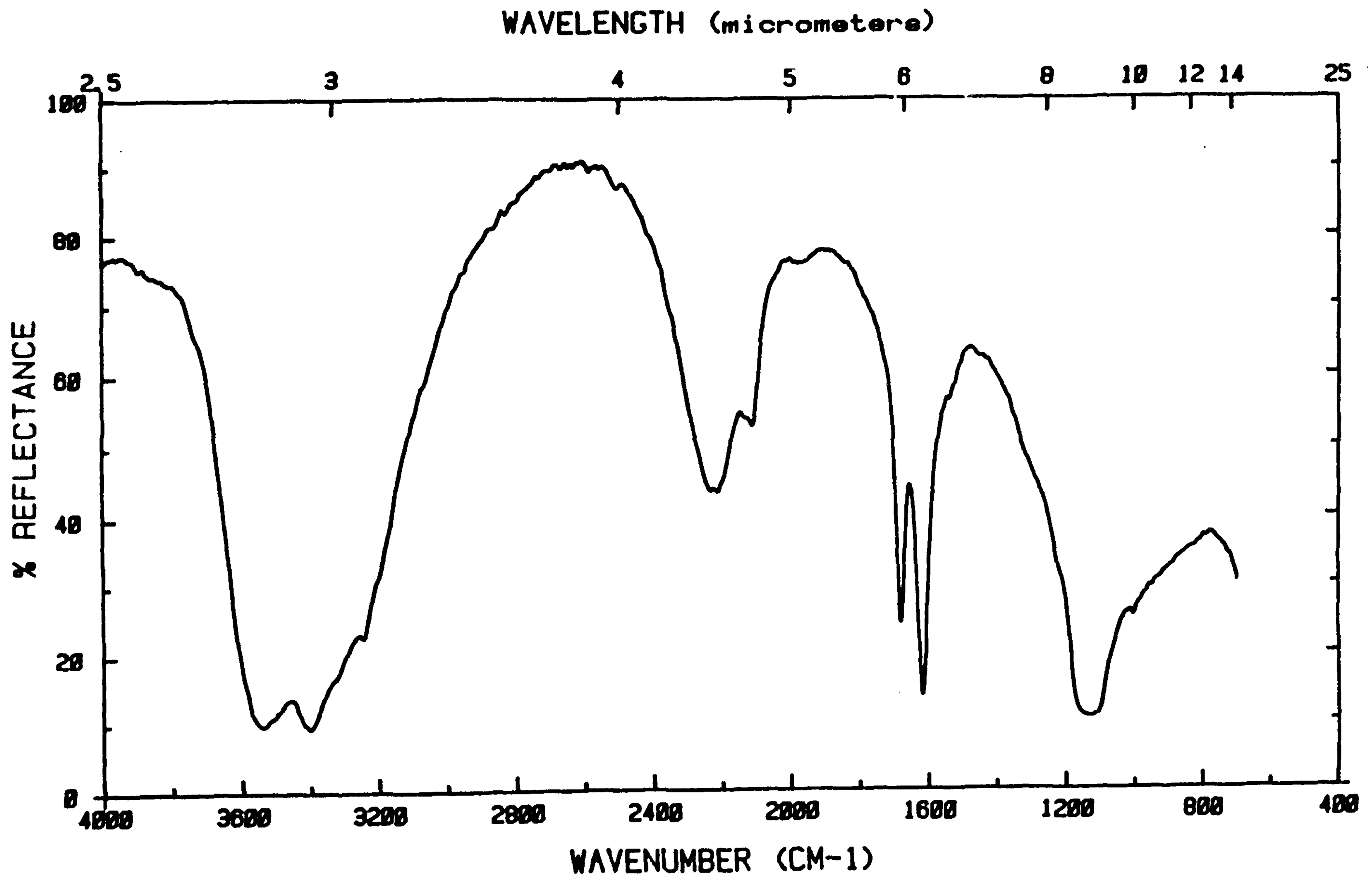
Sample: 10% 0-5 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



25% 0-5 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

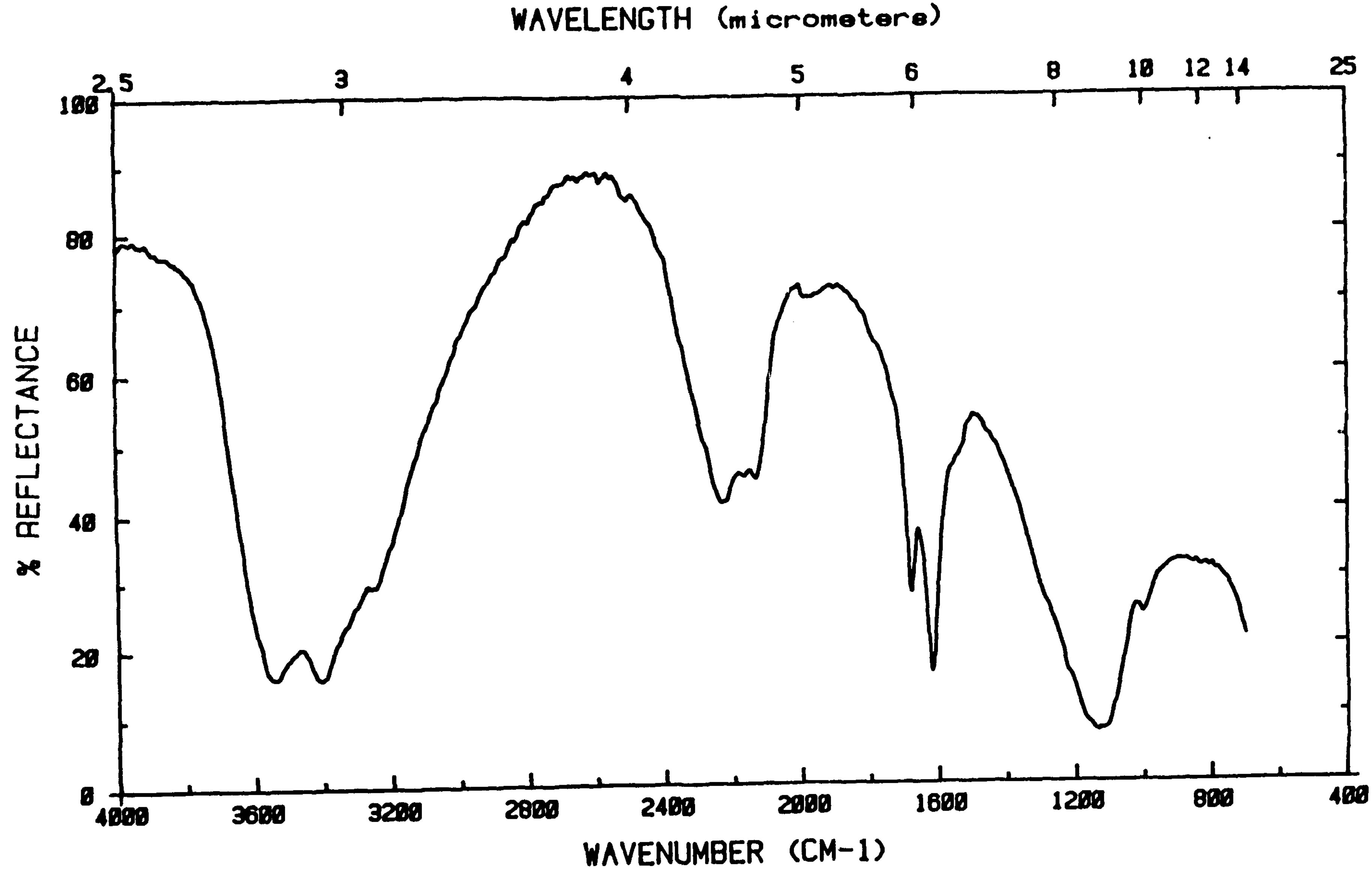
Sample: 25% 0-5 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 0-5 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

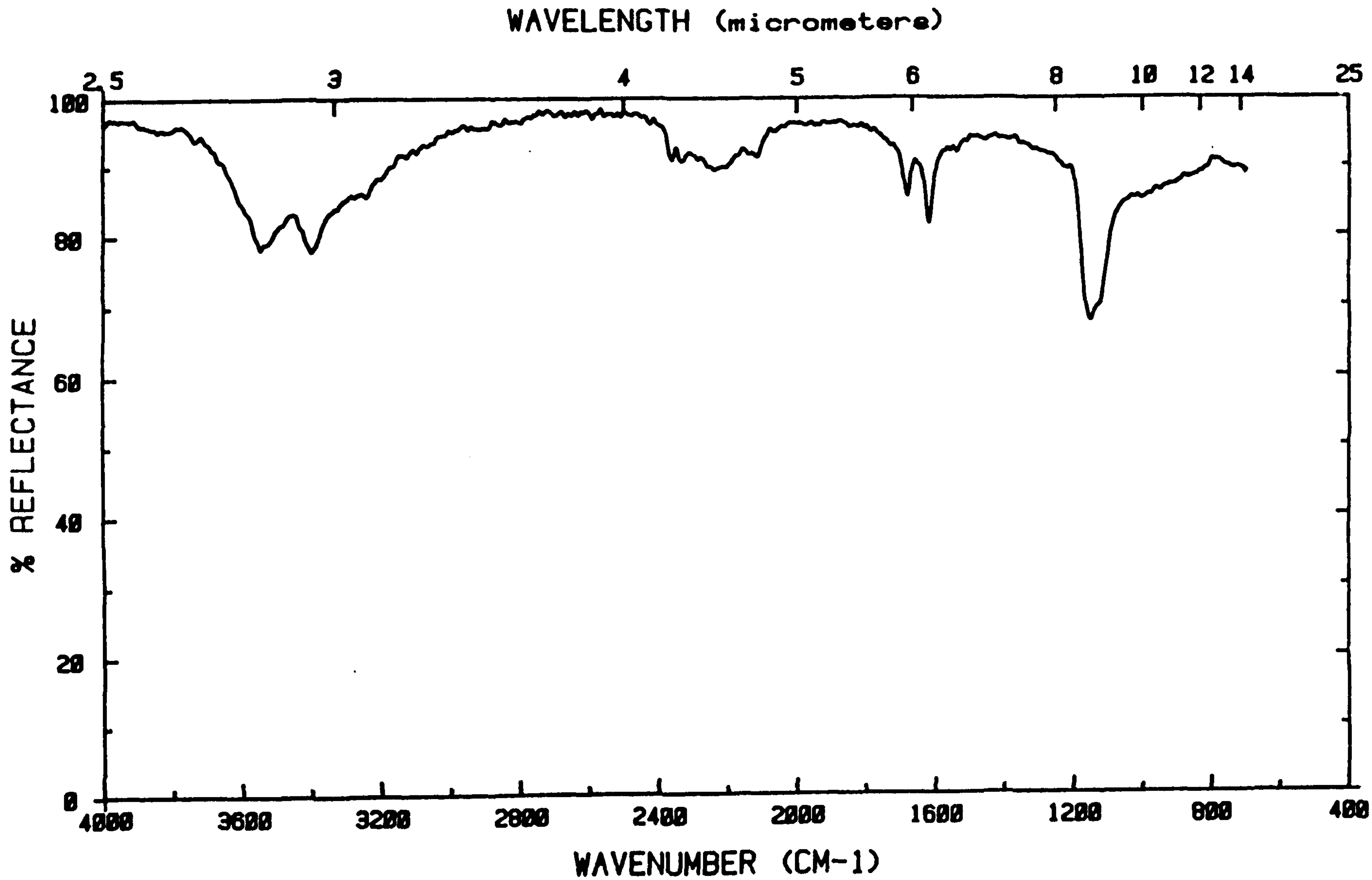
Sample: 50% 0-5 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 0-74 UM PARTICLE SIZE GYPSUM IN NACl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

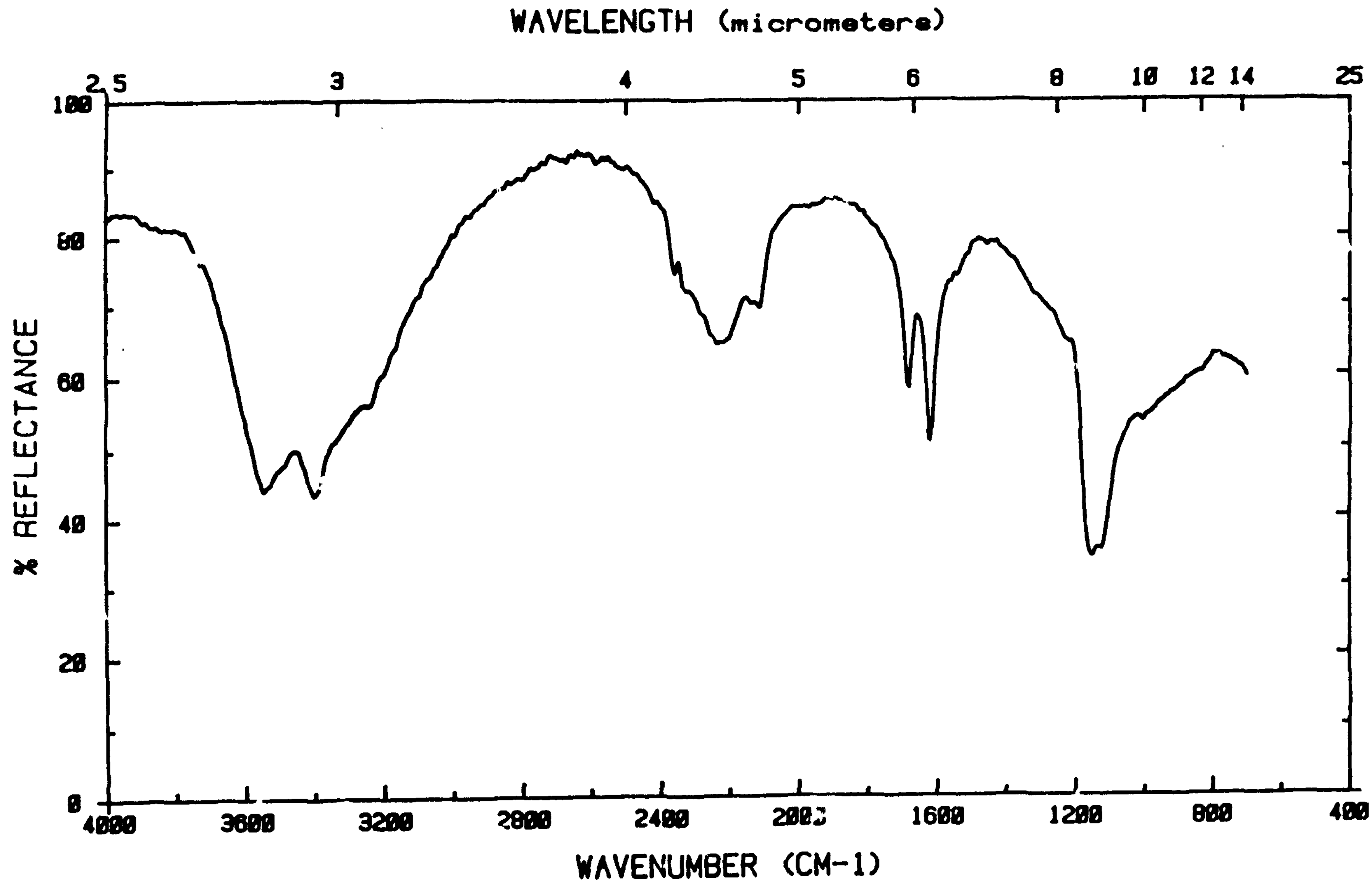
Sample: 2% 0-74 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



10% 0-74 UM PARTICLE SIZE GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

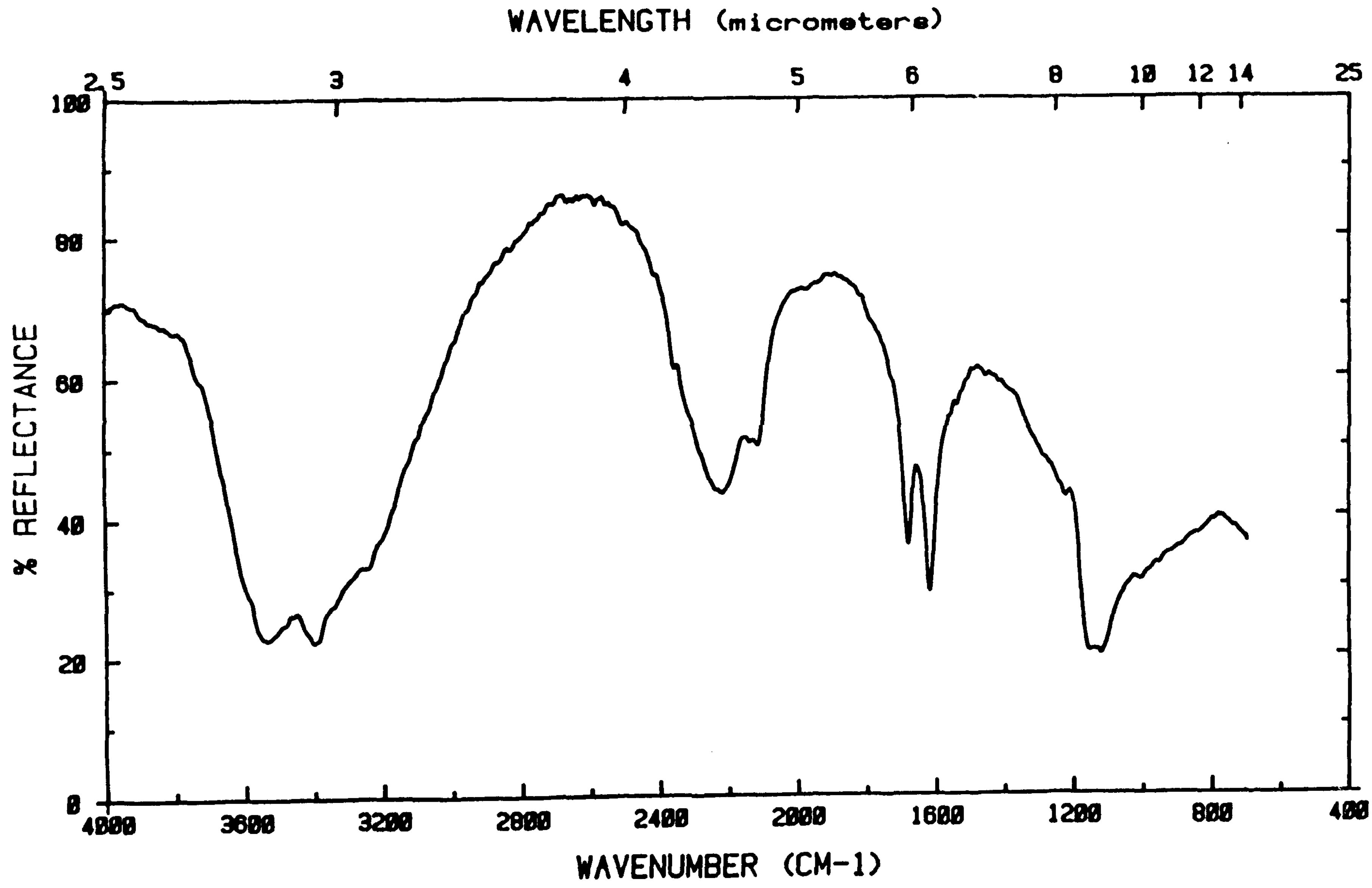
Sample: 10% 0-74 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 0-74 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

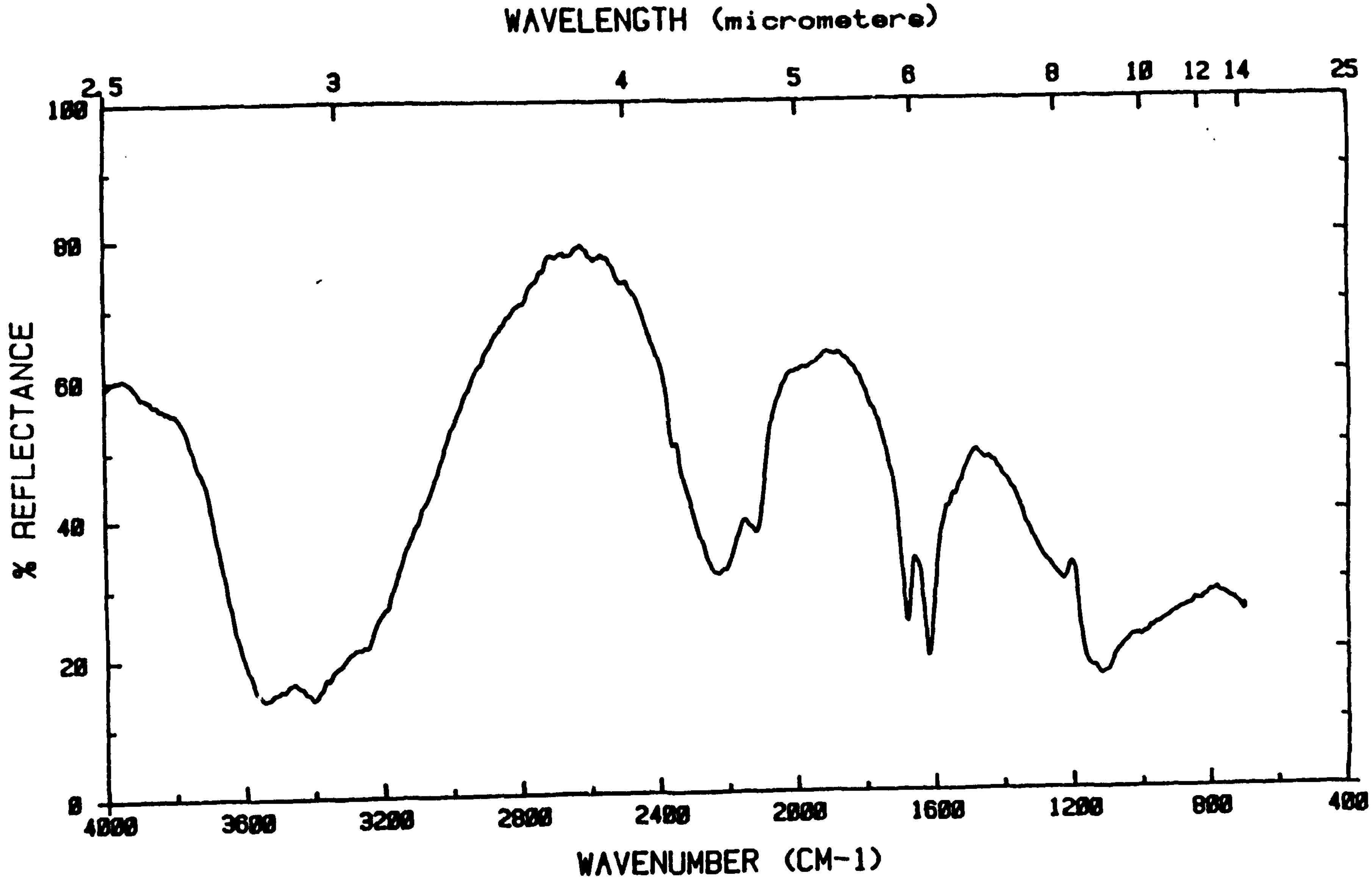
Sample: 25% 0-74 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



50% 0-74 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

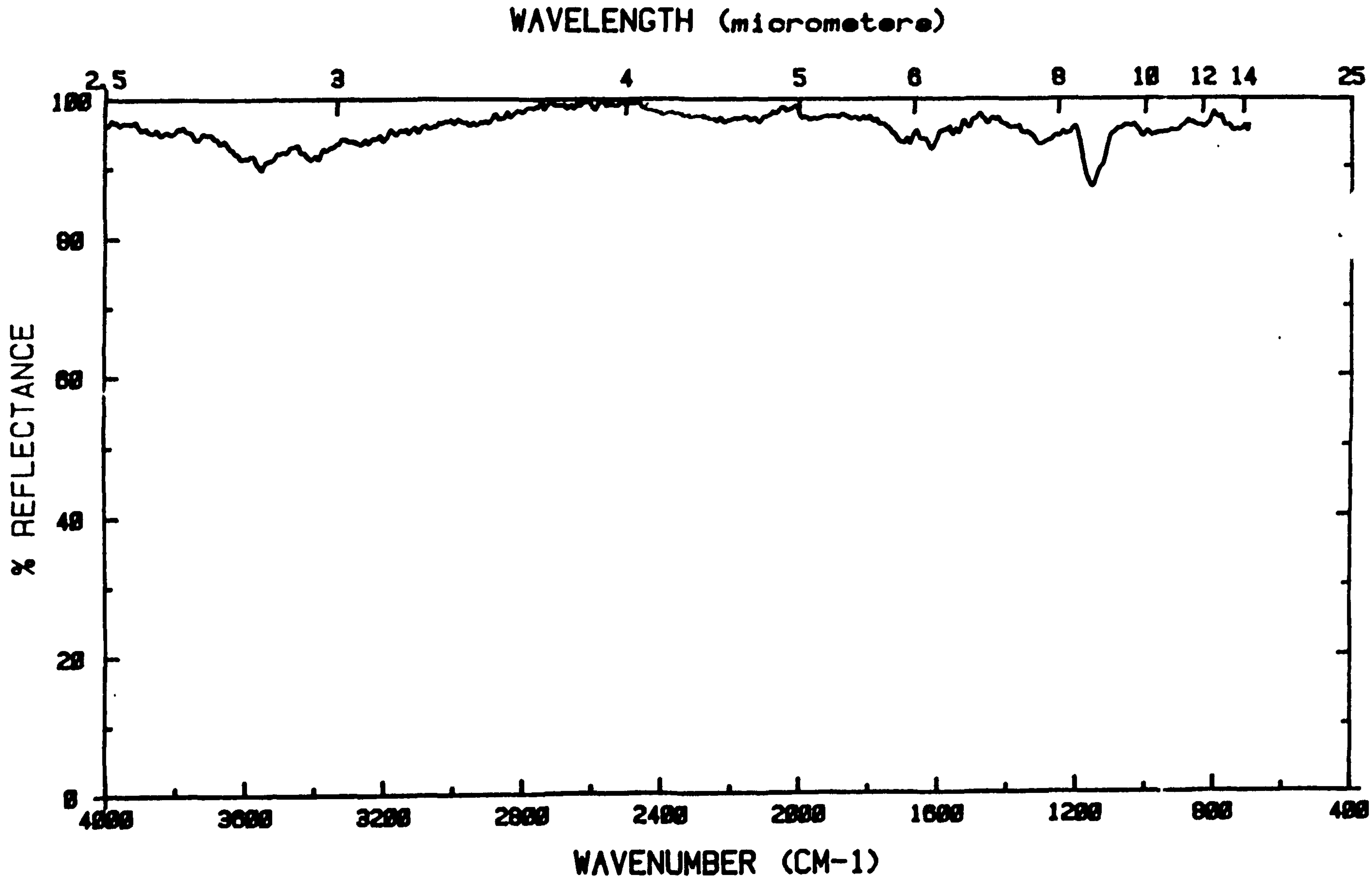
Sample: 50% 0-74 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% 74-250 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

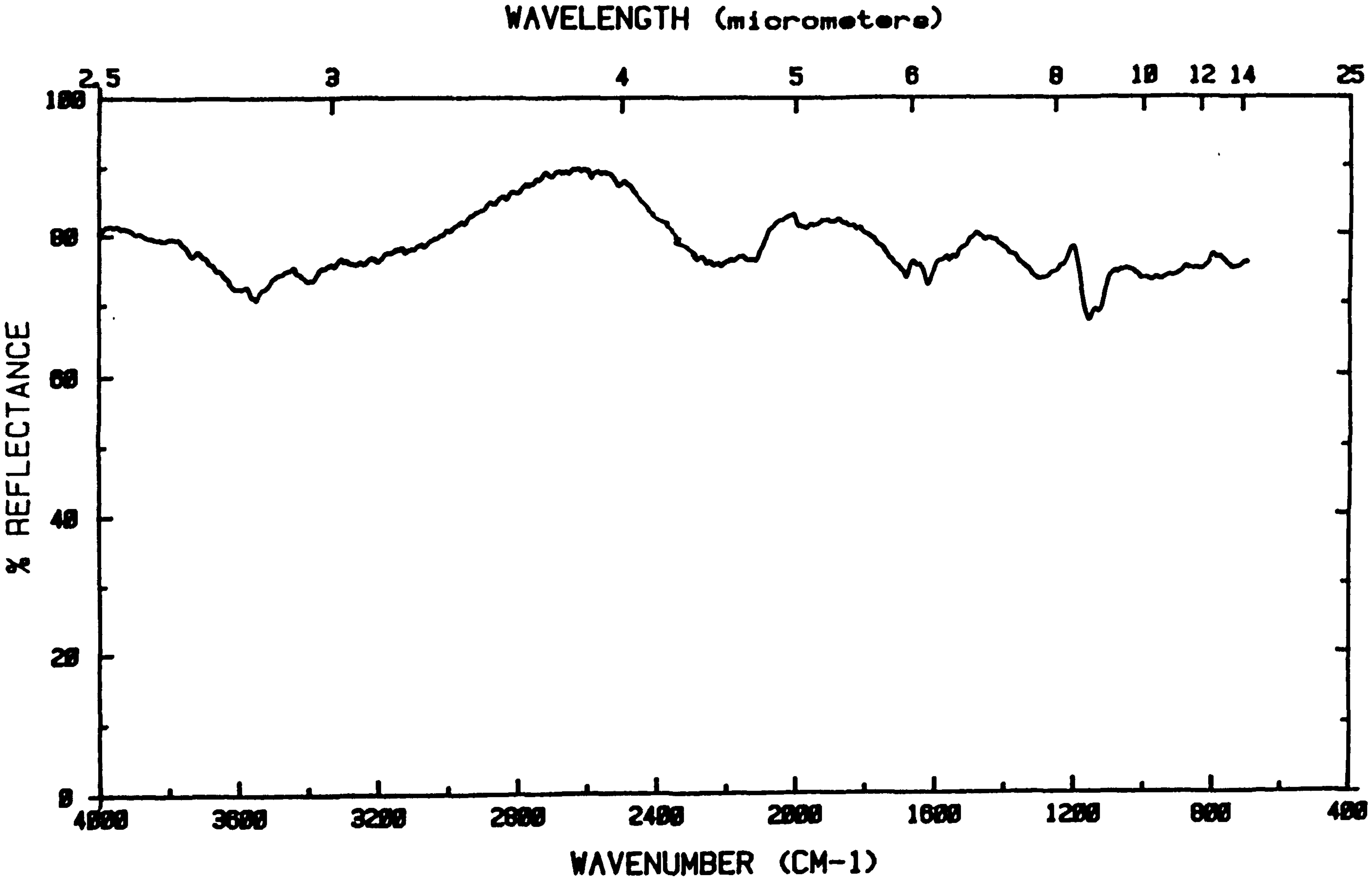
Sample: 2% 74-250 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



10% 74-250 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

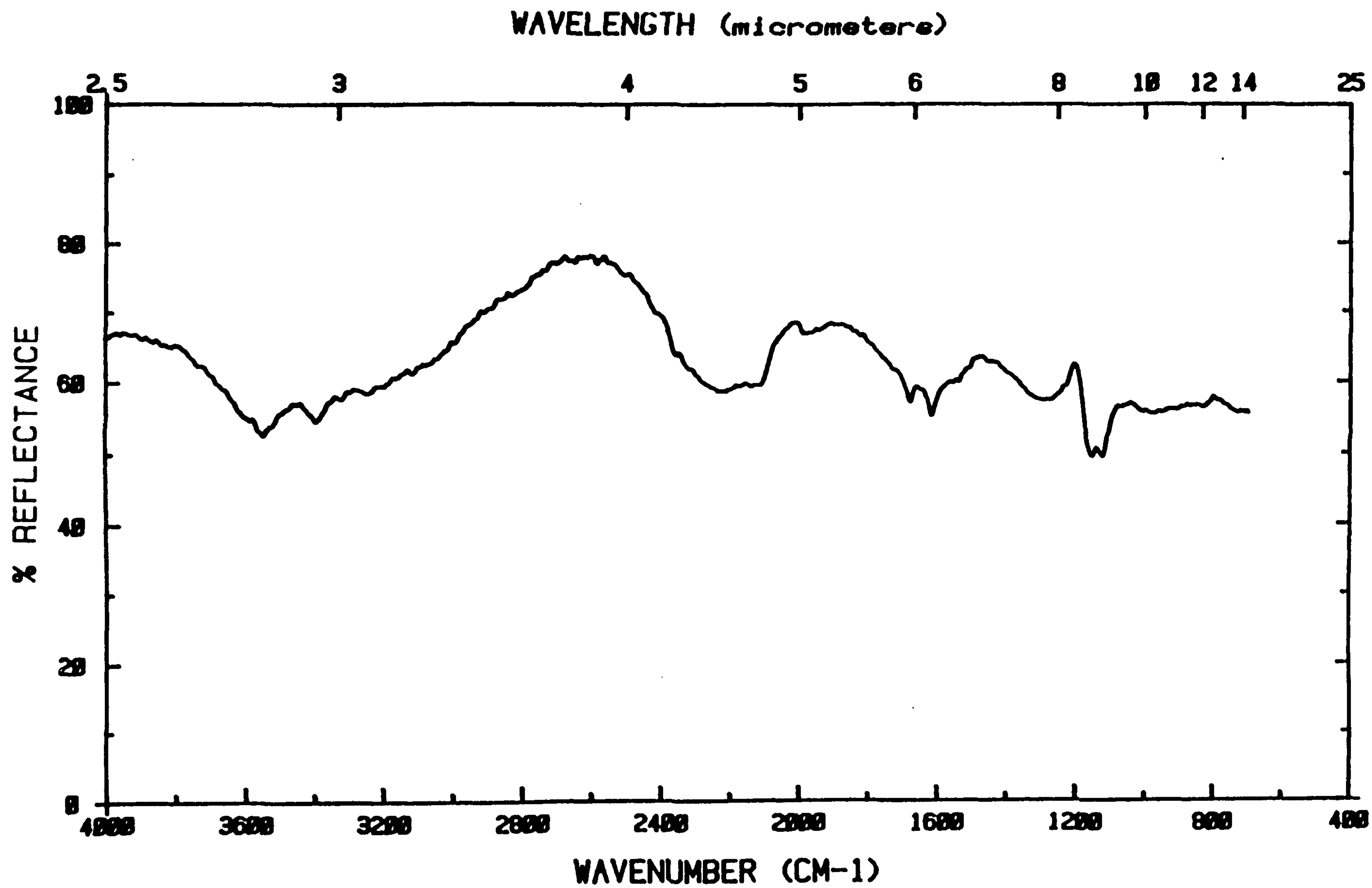
Sample: 10% 74-250 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% 74-250 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

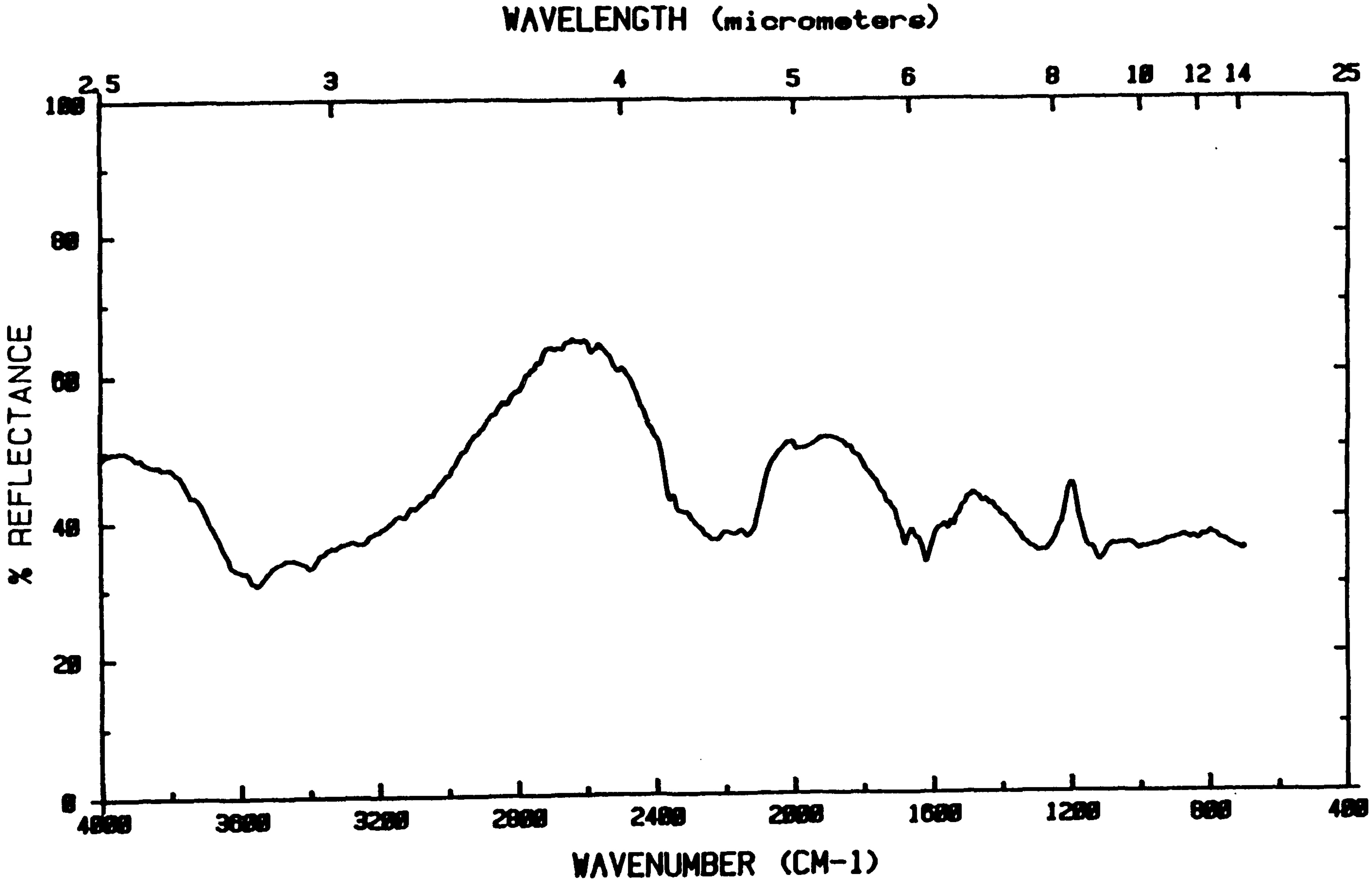
Sample: 25% 74-250 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



50% 74-250 UM GYPSUM IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

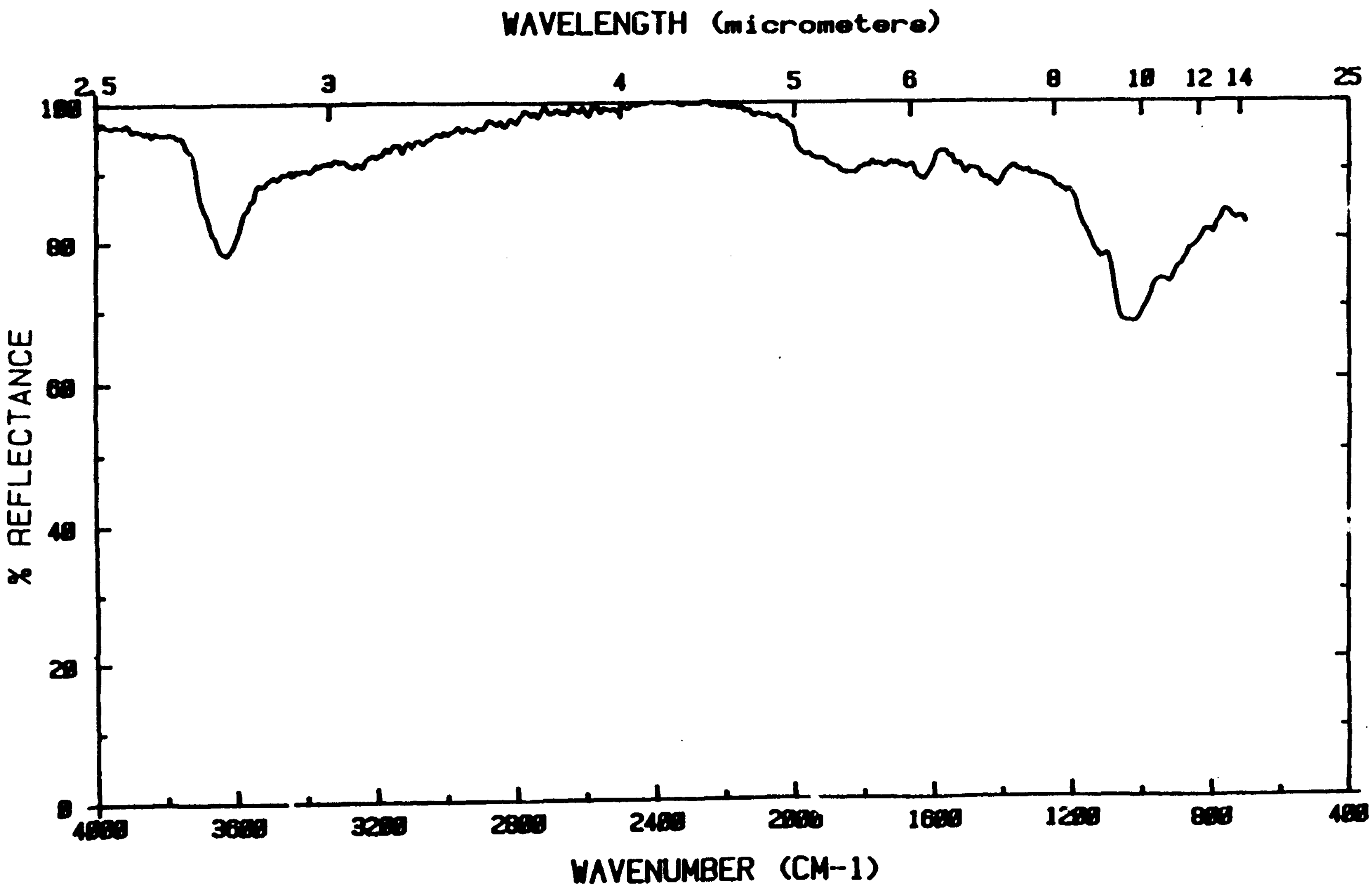
Sample: 50% 74-250 micrometer gypsum in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



2% MONTMORILLONITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

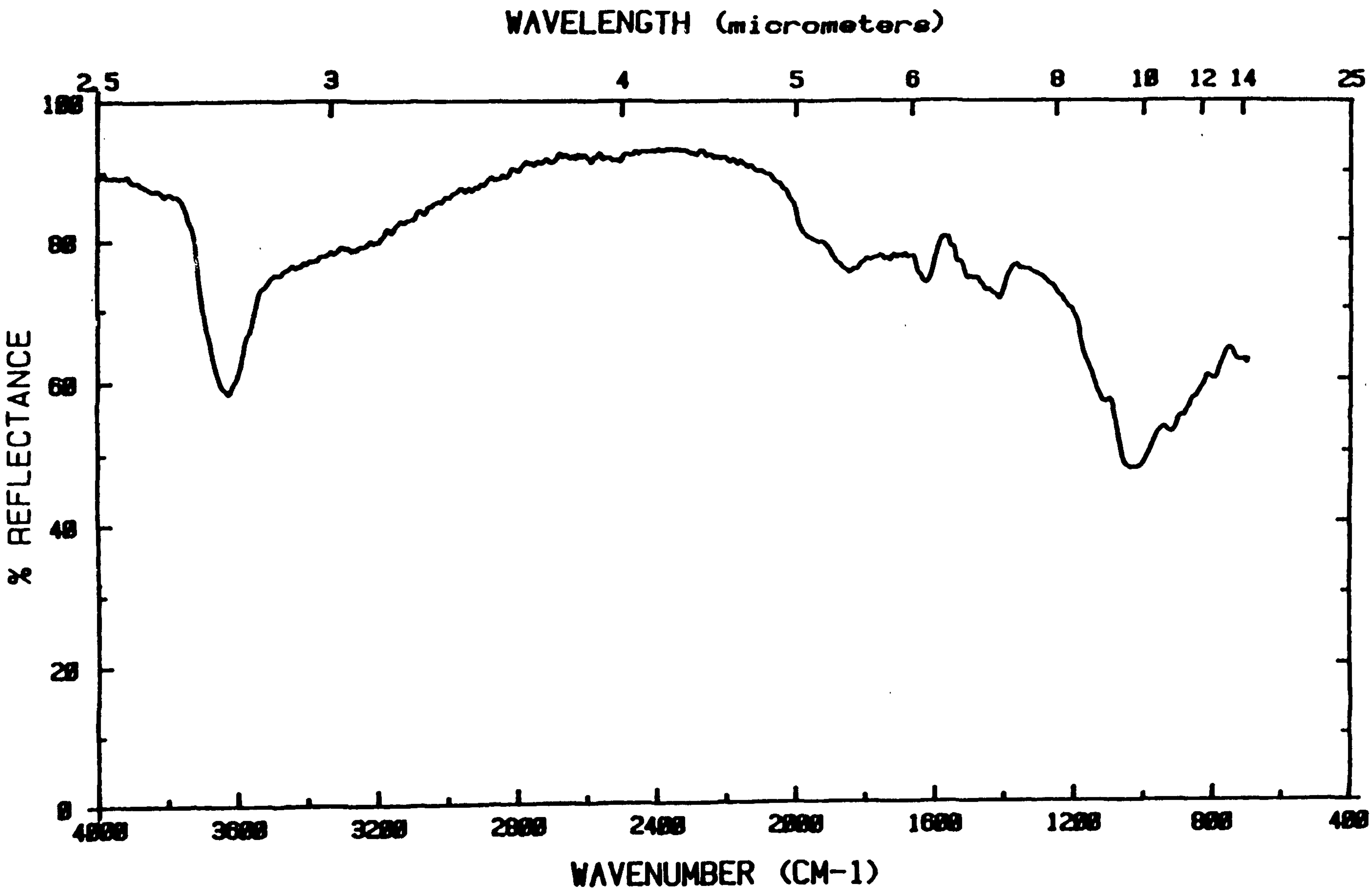
Sample: 2% montmorillonite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



10% MONTMORILLONITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

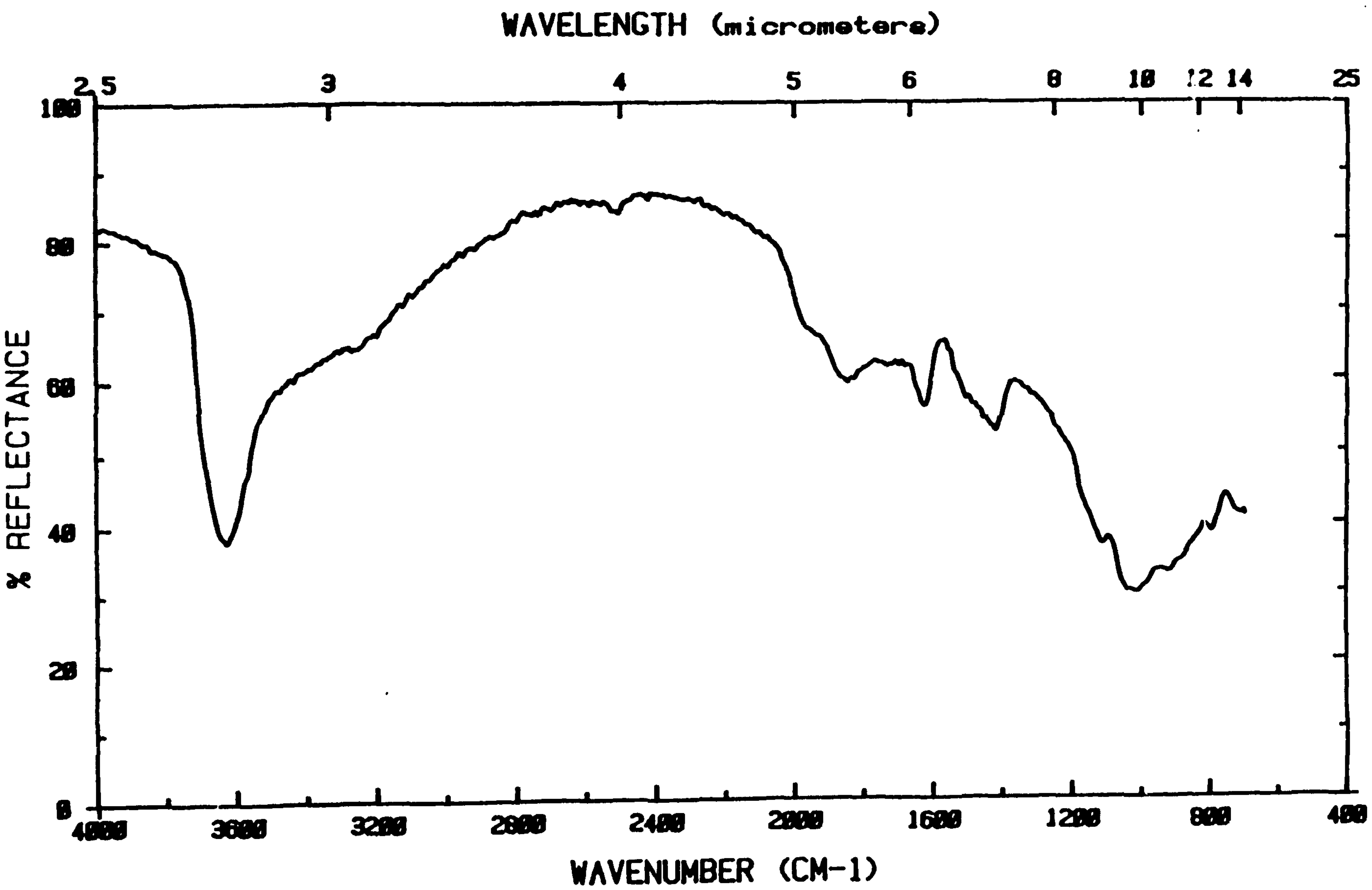
Sample: 10% montmorillonite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



25% MONTMORILLONITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

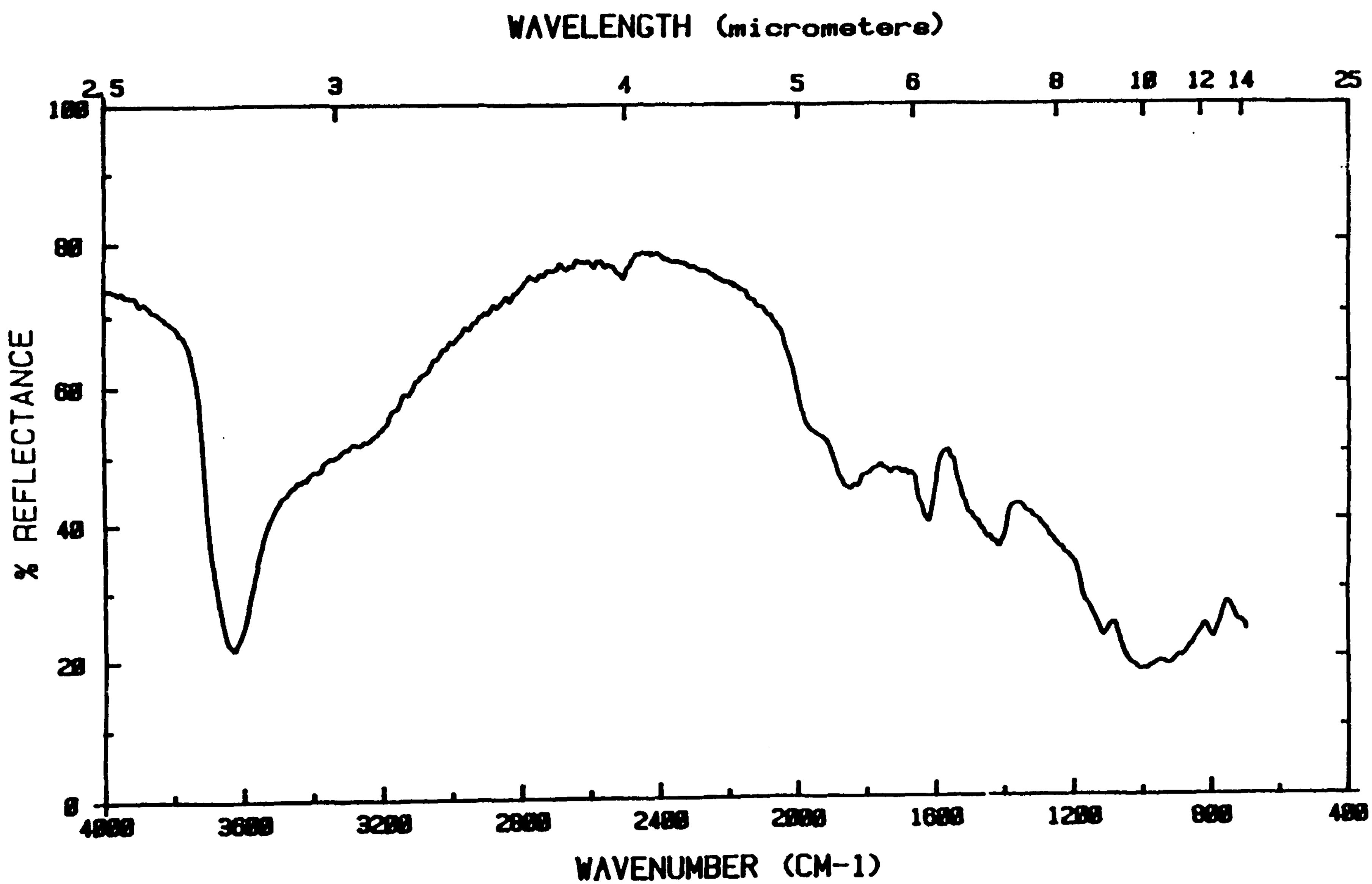
Sample: 25% montmorillonite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, <u>Remote Sensing of Environment</u>, 27: 289-304.



50% MONTMORILLONITE IN NaCl

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

Reference: Particulate NaCl (0-75 micrometers)

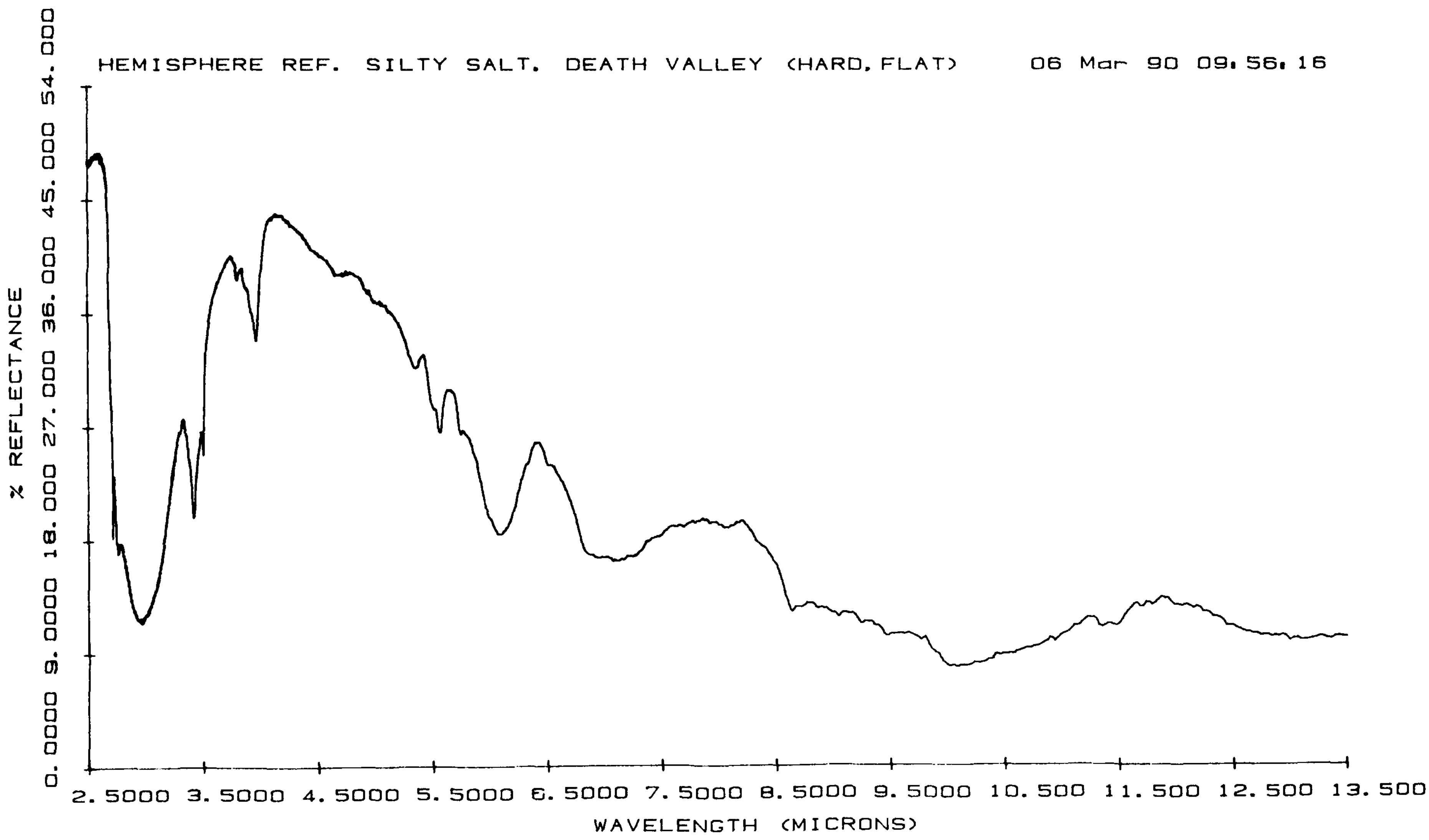
Sample: 50% montmorillonite in NaCl

Origin: Sample is a laboratory construct

Physical state: Particulate mixture

Remarks: This spectrum is part of a study of the spectral characteristics of particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.


HEMISPHERE REF. SILTY SALT. DEATH VALLEY (HARD, FLAT)
06 Mar 90 09:56:16
% REFLECTANCE
0.0000 9.0000 18.000 27.000 36.000 45.000 54.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Silty salt from Death Valley, (hard, flat)

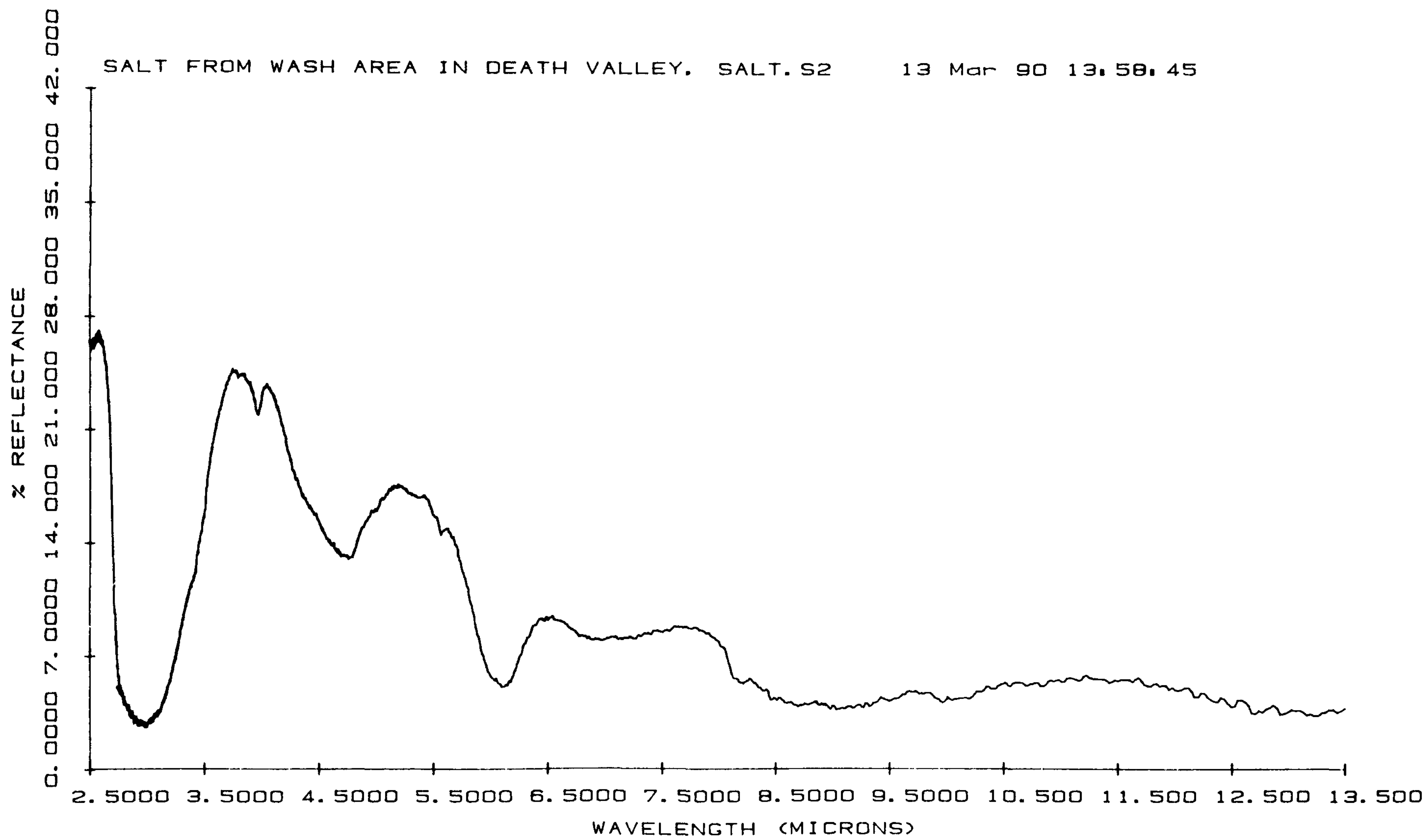
Sample data: Sample collected in April 1989 by J. W. Eastes from silt laden area of the Death Valley salt pan.

Description: This is a hard, flat, smooth sample heavily contaminated with particulate matter. Contaminants consist mainly of clay minerals together with clay and silt sized particles of igneous and sedimentary materials plus organic matter.

Comments: Water absorption appears at 2.9 micrometers and a hydrocarbon C-H stretching feature occurs centered near 3.4 micrometers. A calcite absorption band appears near 4.0 micrometers. The broad depression in reflectance between 8.5 and 12.0 micrometers is the result of overlapping absorption bands of several species such as clays and other finely particulate materials.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



SALT FROM WASH AREA IN DEATH VALLEY. SALT.S2
13 Mar 90 13:58:45
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Salt (halite) from wash area in Death Valley

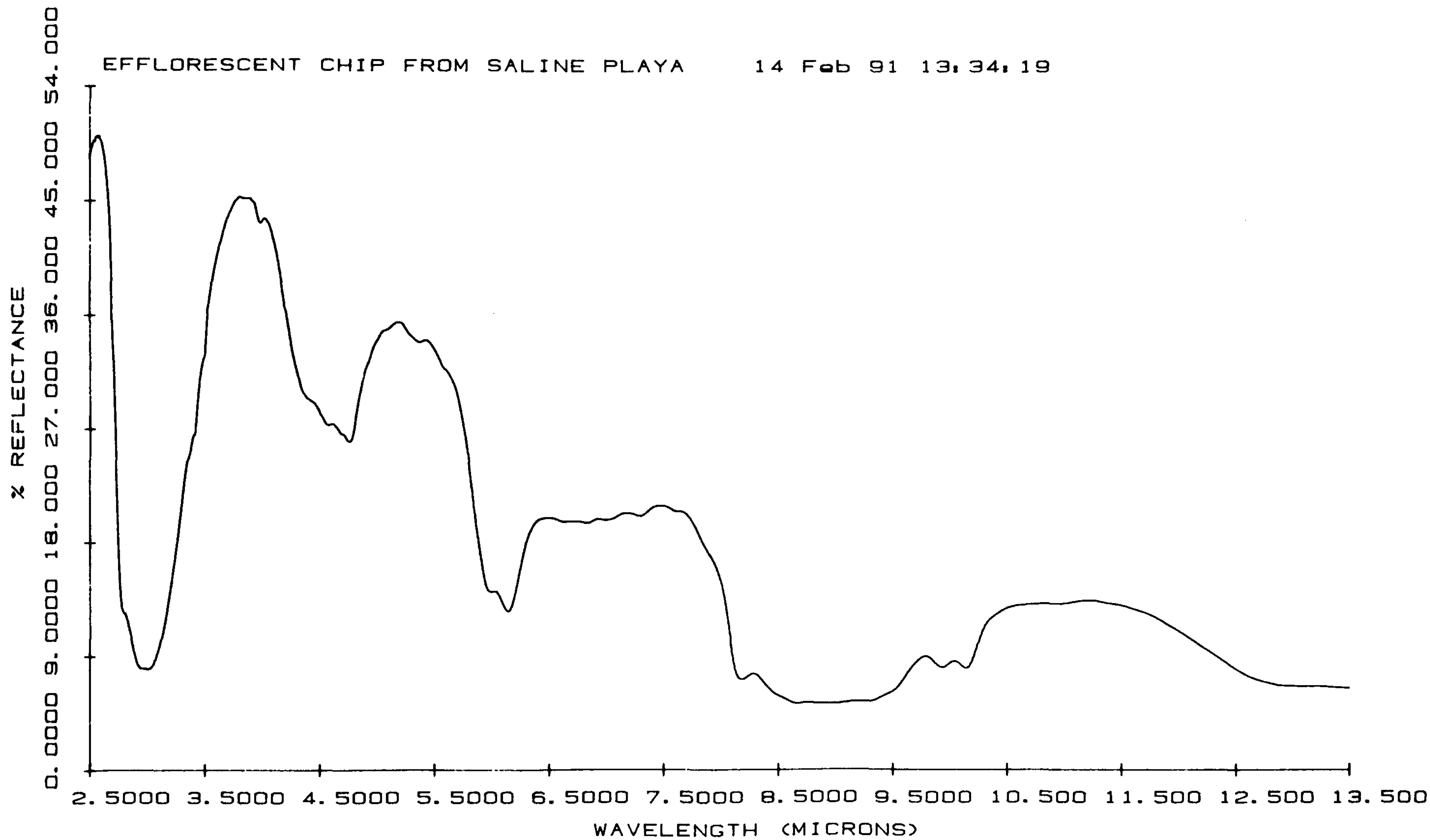
Sample data: Sample collected in April 1989 by J. W. Eastes from Death Valley salt pan.

Description: This is a sample of relatively pure halite from an area of the salt pan washed by surface and subsurface water flow.

Comments: The sample is almost white in color due to low concentrations of colored contaminants. Although not confirmed, an absorption feature near 4.7 micrometers may be due to gypsum. Strong water absorption occurs near 2.9 micrometers and a weak carbonate feature is present near 4.0 micrometers.
Depressed reflectance between 8.0 and 10.5 micrometers is due to absorption by a variety of finely particulate silicate species.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.


EFFLORESCENT CHIP FROM SALINE PLAYA 14 Feb 91 13:34:19
% REFLECTANCE
0.0000 9.0000 18.000 27.000 36.000 45.000 54.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

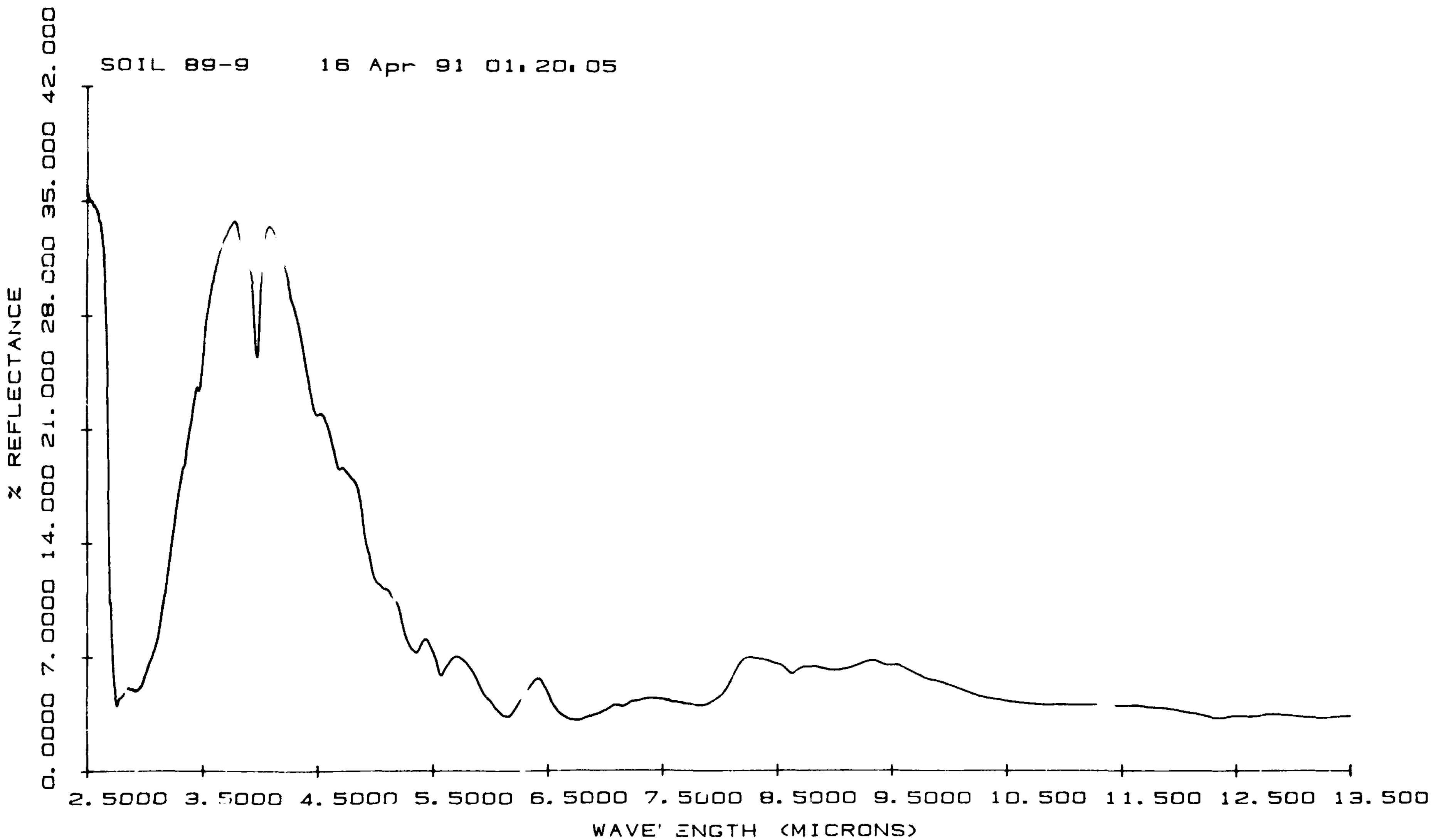
Sample: Efflorescent chip

Sample data: Sample collected by M. B. Satterwhite and J.P Henley during field work in the Mojave desert.

Description: Sample is a small chip of soil from a Mojave desert saline playa having an approximately 1 mm thick efflorescence on the surface.

Comments: This spectrum illustrates the effects of finely divided particulate material dispersed in a saline matrix. The spectrum differs from those of pure minerals in that spectral features in the region between approximately 8 and 10.3 micrometers are expressed as reflectance minina rather than maxima. The spectral minima result from absorption by finely particulate silicates and other materials dispersed in the efflorescent crust. These finely divided contaminents in the efflorescent crust can be introduced by both wind and water.

Reference: Eastes, John W. (1989), Spectral Properties of Halite-Rich Mineral Mixtures: Implications for Middle Infrared Remote Sensing of Highly Saline Environments, Remote Sensing of Environment, 27: 289-304.



SOIL 89-9 16 Apr 91 01:20:05
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-9

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Danby Lake, San Bernardino Co. CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

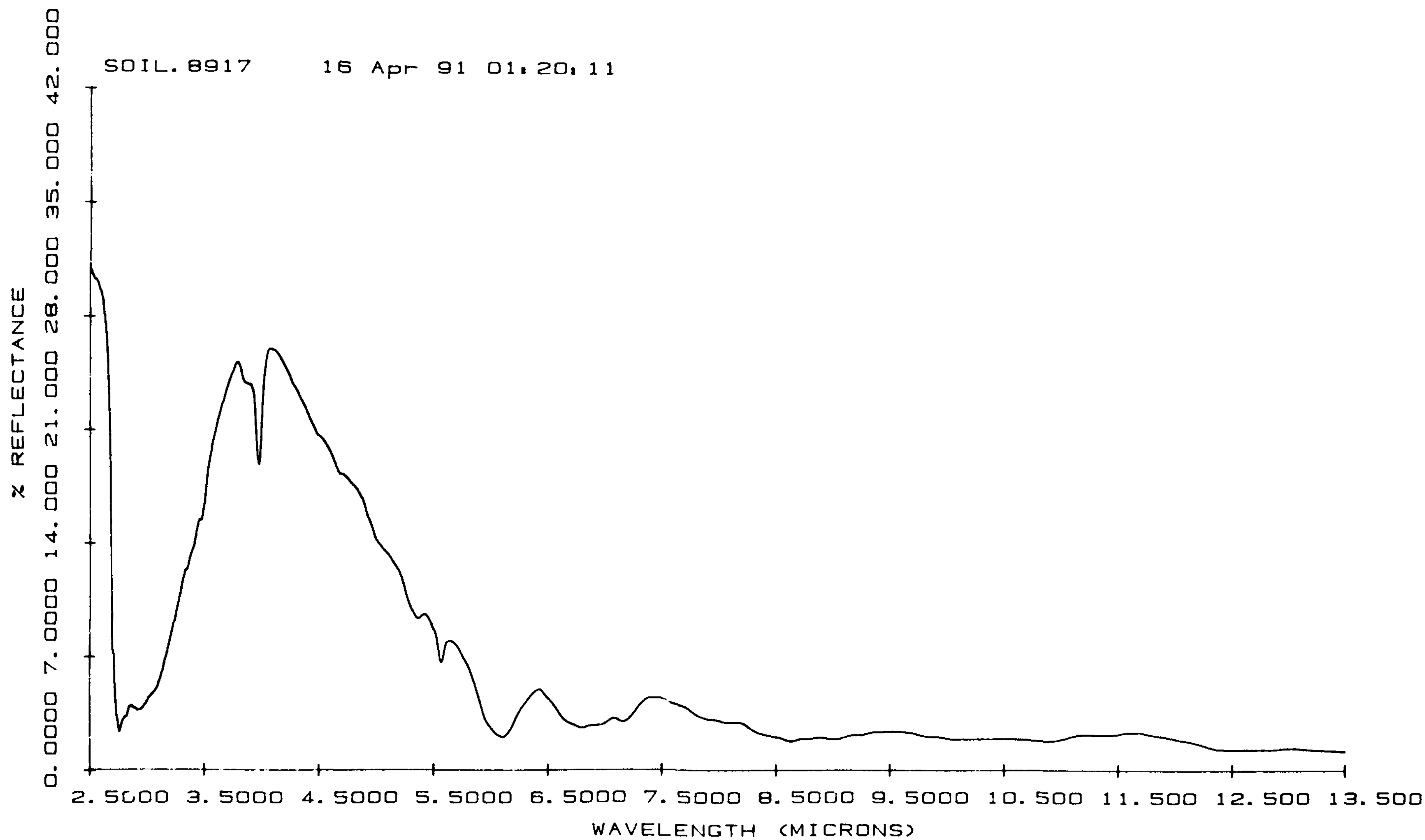
Description: This is a poorly-sorted, subangular (grain shape), buff-colored, very fine-grained subfeldspathic gypsiferous quartz sand. The bladed gypsum crystals are clear to white (coated with calcite) and display twinning.

XRD analysis: XRD analysis determined a 16% plagioclase, 6% K-feldspar, 6% calcite and 1% clay minerals for the sample. Petrographic analysis further indicated 40% quartz and 35% gypsum. The clay mineral component consists of illite, smectite, mixed-layered illite/smectite, kaolinite and chlorite. Augite and rhodochrosite are present as trace amounts in the clay fraction.

Comments: Hydroxyl absorption associated with clay minerals together with a water absorption band appear in the 2.7-2.9 micrometer region. This sample contains considerable gypsum (35%), however except for water absorption, gypsum spectral features appear to be masked by quartz or other species. A weakly expressed broad doublet between 8 and 9.5 micrometers is diagnostic of quartz. Calcite absorption occurs near 4.0 micrometes and a weak carbonate fundamental, also due to calcite, appears near 6.4 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL.8917
16 Apr 91 01:20:11
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-17

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Danby Lake, San Bernardino Co., CA . Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

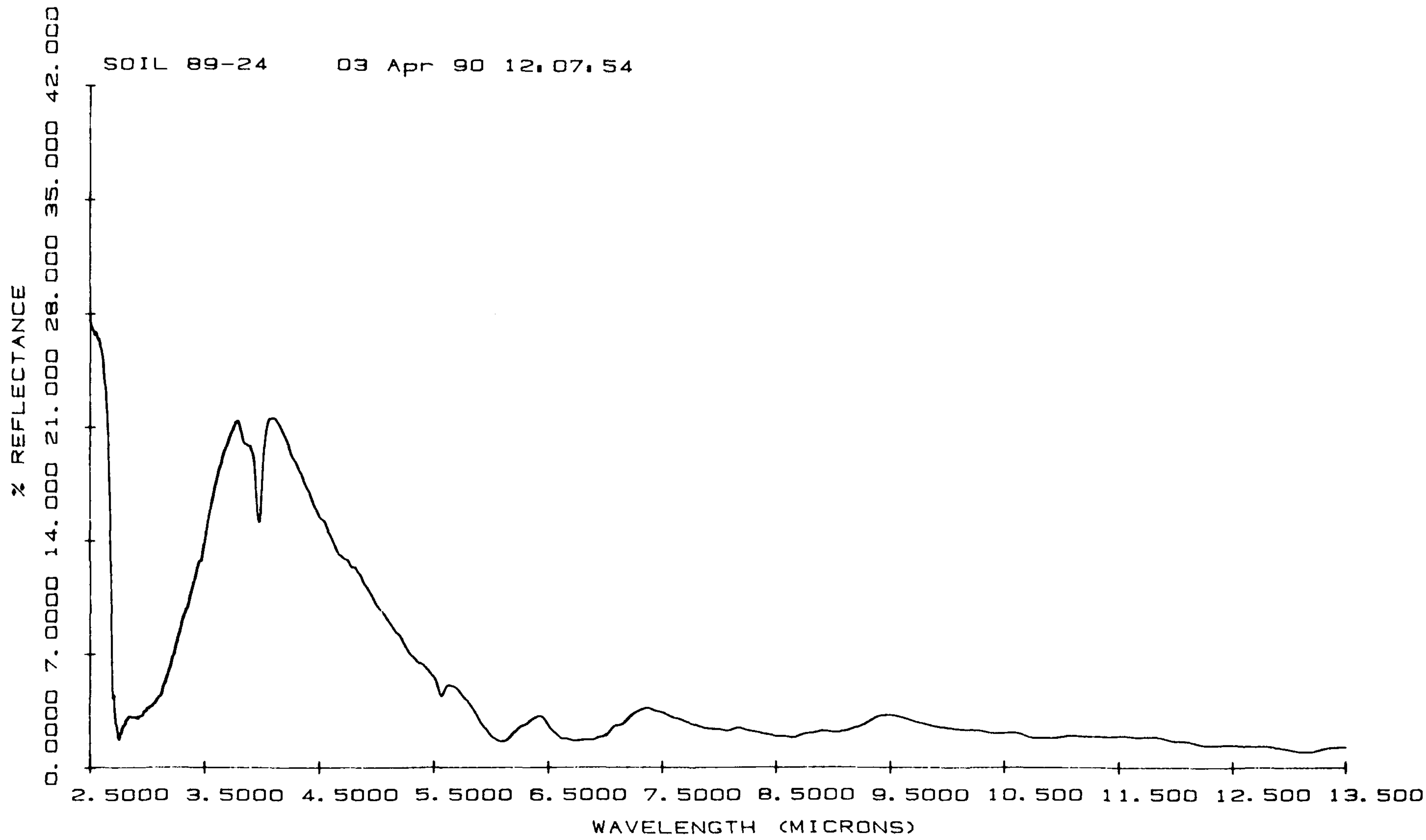
Description: This is a well sorted, light-buff, very fine-grained subfeld-spathic calcareous quartz silt.

XRD analysis: Sample consists of 73% quartz, 10% feldspar (oligoclase), 16% calcite, and 1% clay minerals. Quartz, calcite and oligoclase are in the silt-sized fraction. Clay minerals consist of illite, smectite, mixed-layered illite/smectite, chlorite and kaolinite.

Comments: XRD analysis indicates a high (73%) quartz content for this sample, however fine sample particle size results in low spectral contrast in the 8 to 13.5 micrometer region of the spectrum. A narrow calcite absorption band occurs near 4.0 micrometers and and a surface scattering reflectance peak, also due to calcite, appears near 6.3 micrometers. Hydroxyl absorption due to clay minerals plus a water band appear in the 2.7-2.9 micrometer region.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL 89-24
03 Apr 90 12.07.54
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-24

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Silver Lake, San Bernardino Co., CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

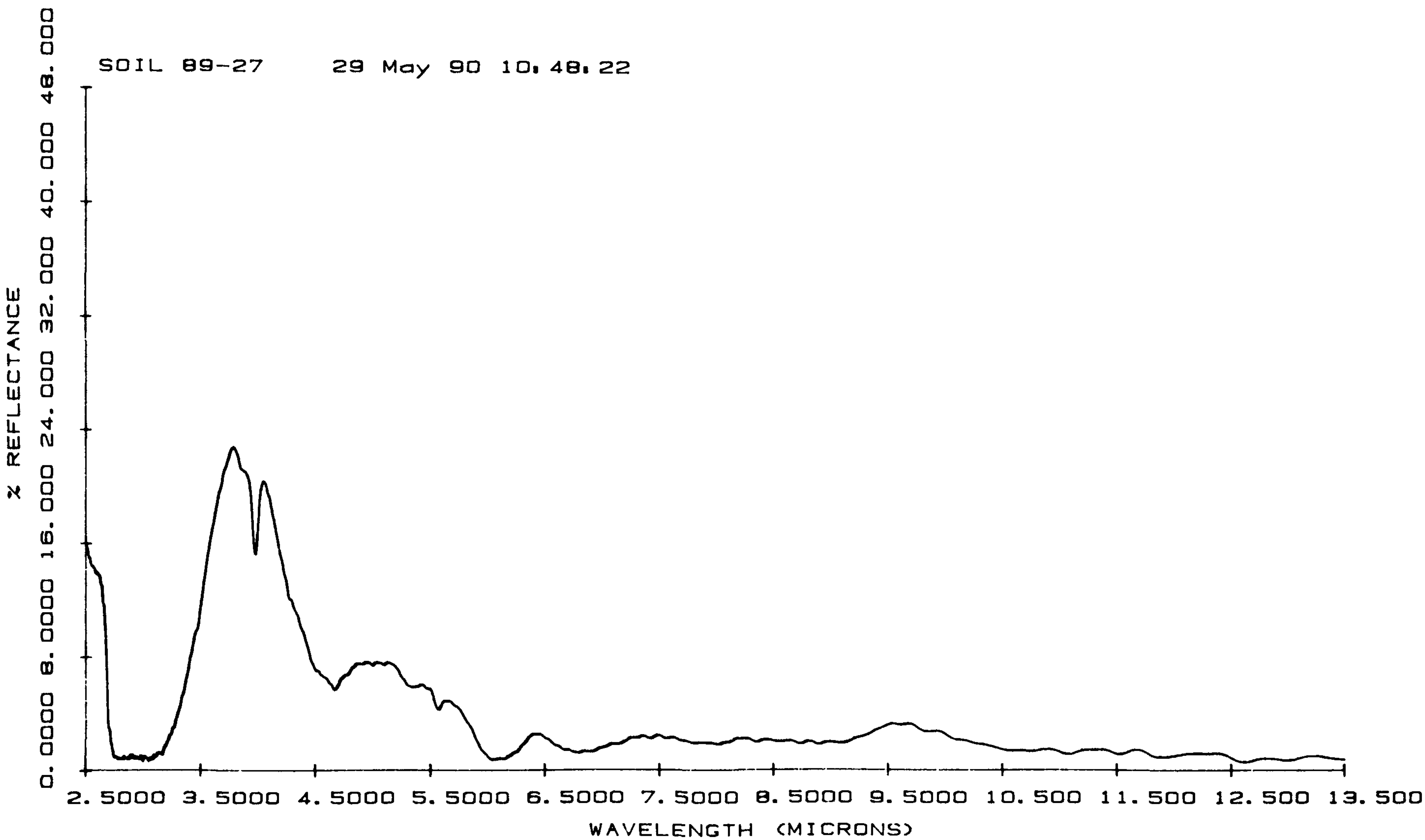
Description: This is a well-sorted, medium buff-colored, very fine-grained calcareous subfeldspathic quartz silt.

XRD analysis: Sample consists of 81% quartz, 11% feldspar (Na-rich plagio-clase), 8% calcite and 1% clay minerals. The clay fraction contains illite (K-clay), mixed-layered illite/smectite, smectite, kaolinite and a trace of microcline.

Comments: Although XRD analysis indicates a high silicate content for this sample, fine particle size produces low spectral contrast in the 8 to 13.5 micrometer Si-O stretching region of the spectrum. A weak maximum due to clay minerals is seen centered near 9.5 micrometers. A calcite reflectance maximum appears near 6.4 micrometers while calcite absorbance occurs near 4.0 micrometers. A water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to clay in the soil.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL 89-27
29 May 90 10:48:22
% REFLECTANCE
0.0000
8.0000
16.000
24.000
32.000
40.000
48.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-27

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Bristol Lake, San Bernardino Co., CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

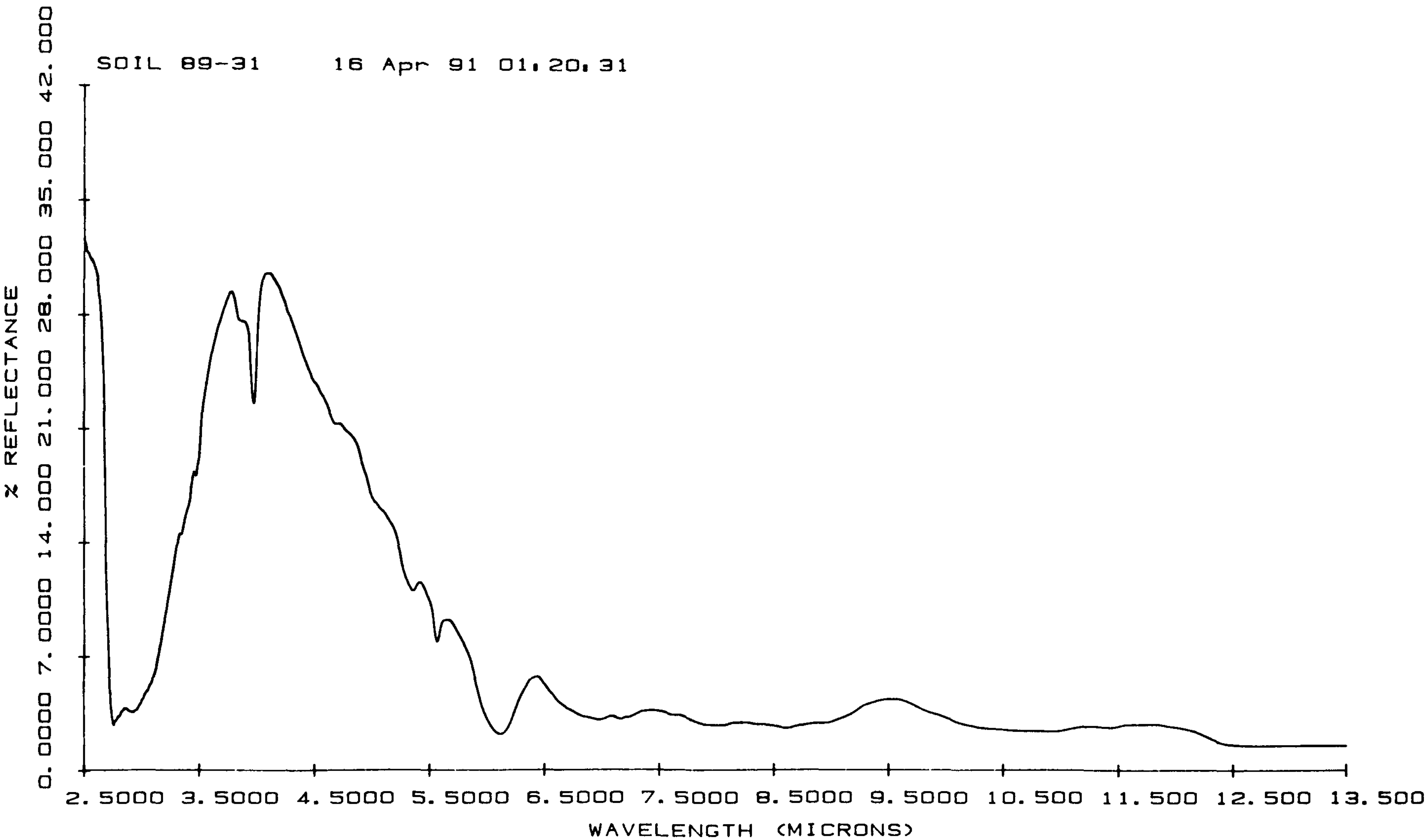
Description: This sample is a light orange-brown colored, fine-grained calcareous subfeldspathic quartz sand. The color is due to hematite coating individual sand grains. The calcite is white, the quartz grains are clear to orangish-brown, and the feldspar is white to pink.

XRD analysis: Sample consists of 62% quartz, 14% calcite, 23% feldspar (12% albite, 11% K-feldspar) and 1% clay minerals. The clay fraction is made up of illite, mixed-layered illite/smectite, smectite and chlorite.

Comments: XRD analysis indicates a high quartz content for this sample, however fine sample particle size produces low spectral contrast in the 8 to 13.5 micrometer Si-O stretching region. A moderate clay mineral reflectance peak is centered about 9.6 micrometers. Hydroxyl and water absorption appears between 2.7 and 2.9 micrometers due to clay minerals. Moderate calcite absorption appears near 4.0 micrometers and the carbonate fundamental reflectance peak, also due to calcite, occurs near 6.3 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-31 16 Apr 91 01:20:31
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-31

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Broadwell Lake, San Bernardino Co, CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

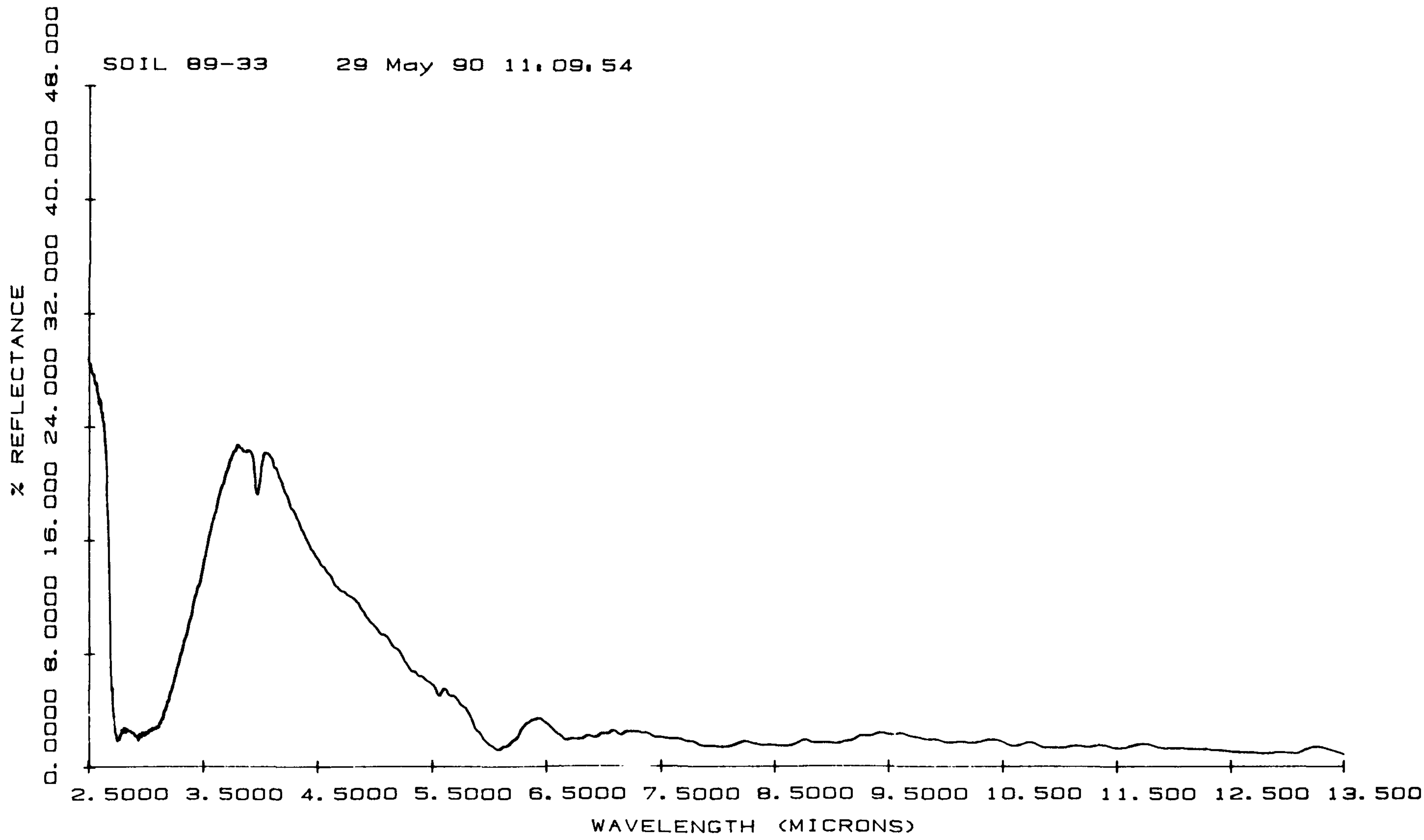
Description: This is a well sorted, buff-colored, very fine-grained subfeldspathic dolomitic calcareous quartz silt. The dolomite consists of minute flakes with a vitreous luster (crystals reflect light) and the calcite is white. The sample also contains minor amounts of muscovite and biotite as well as organic material (small twigs).

XRD analysis: Sample consists of 61% quartz, 14% calcite, 11% dolomite and rhodochrosite 13% feldspar (albite) and 1% clays. The clay fraction contains mixed-layered illite/smectite, smectite, illite and minor chlorite.

Comments: XRD analysis indicates a high quartz content for this sample, however fine sample particle size causes low spectral contrast in the 8 to 13.5 micrometer wavelength region. Hydroxyl and water absorptions appear in the 2.7-2.9 micrometer region. Carbonate absorption due to calcite occurs near 4.0 micrometers and carbonate fundamental reflectance appears near 6.4 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-33 29 May 90 11:09:54
% REFLECTANCE
0.0000
8.0000
16.000
24.000
32.000
40.000
48.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-33

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Superior playa near Ft. Irwin, CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

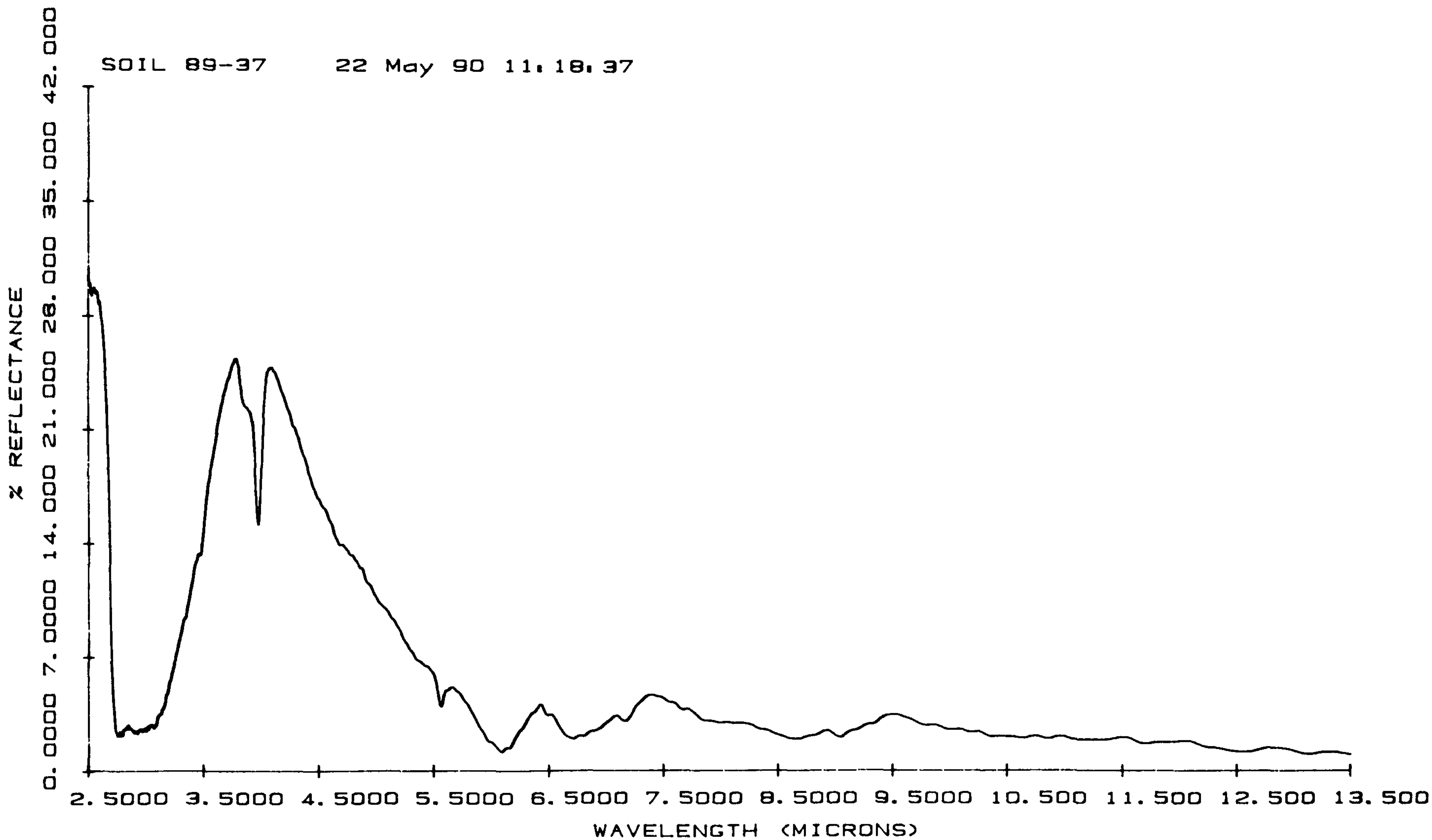
Description: This is a well-sorted, light-buff colored, fine-grained calcareous quartz silt containing quartz and calcite in the silt-fraction and feldspar in the clay-fraction.

Comments: XRD analysis indicates a considerable (49%) quartz content for this sample, however because of fine sample particle size, spectral contrast in the 8 to 13.5 micrometer Si-O stretching region of the spectrum is very weakly expressed. Clay mineral hydroxyl absorption appears at 2.7 micrometers, and a water band occurs near 2.9 micrometers. Weak carbonate absorption is seen near 4.0 micrometers, and a weak carbonate surface scattering peak appears near 6.3 micrometers.

XRD analysis: Sample consists of 49% quartz, 40% feldspar (19% microcline; K-feldspar & 21% albite; Na-plagioclase), 10% calcite and 1% clay minerals. The clays consist of mixed-layered illite/smectite, illit, smectite and kaolinite.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples,</u> A report prepared for U.S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-37
22 May 90 11:18:37
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-37

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Coyote Lake, San Bernardino Co., CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

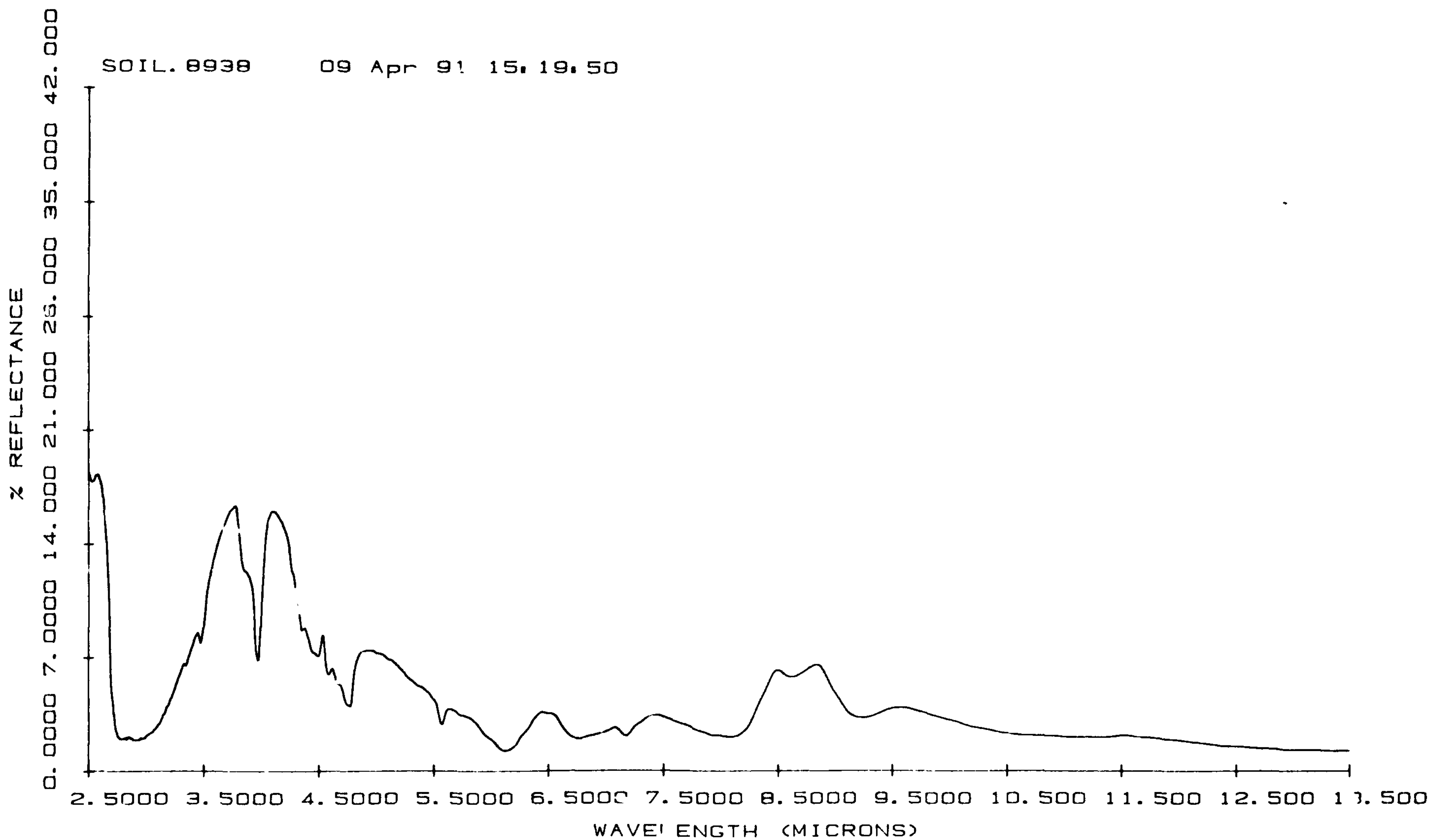
Description: This is a moderately-sorted, subangular (grain shape), light-buff colored, fine-grained sandy silt containing quartz, feldspar/plagioclase, calcite, magnetite and brown mica.

XRD analysis: Sample consists of 59% quartz, 20% plagioclase (laboradorite), 20% calcite, and 1% clay minerals (predominately mixed-layered illite/ smectite). The 1% clay fraction consists of mixed-layered illite/smectite (72%), illite (23%) and kaolinite (5%).

Comments: XRD analysis indicates a high silicate content for this sample, however fine sample particle size causes spectral features in the 8 to 13 micrometer Si-O stretching region of the spectrum to be weakly expressed. A weak reflectance peak centered around 9.5 micrometers may be due to plagioclase. Calcite absorption occurs near 4.0 micrometers and a calcite reflectance peak appears near 6.4 micrometers. A broad water band at 2.9 micrometers together with a sharper hydroxyl band at 2.7 micro-meters due to O-H stretching vibrations are due to the small amount of clay in the soil. Clay coatings on quartz grains may account in part for the lack of a characteristic quartz doublet normally found near 8.5 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL.8938 09 Apr 91 15:19:50
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-38

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Coyote Lake, San Bernardino Co. CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

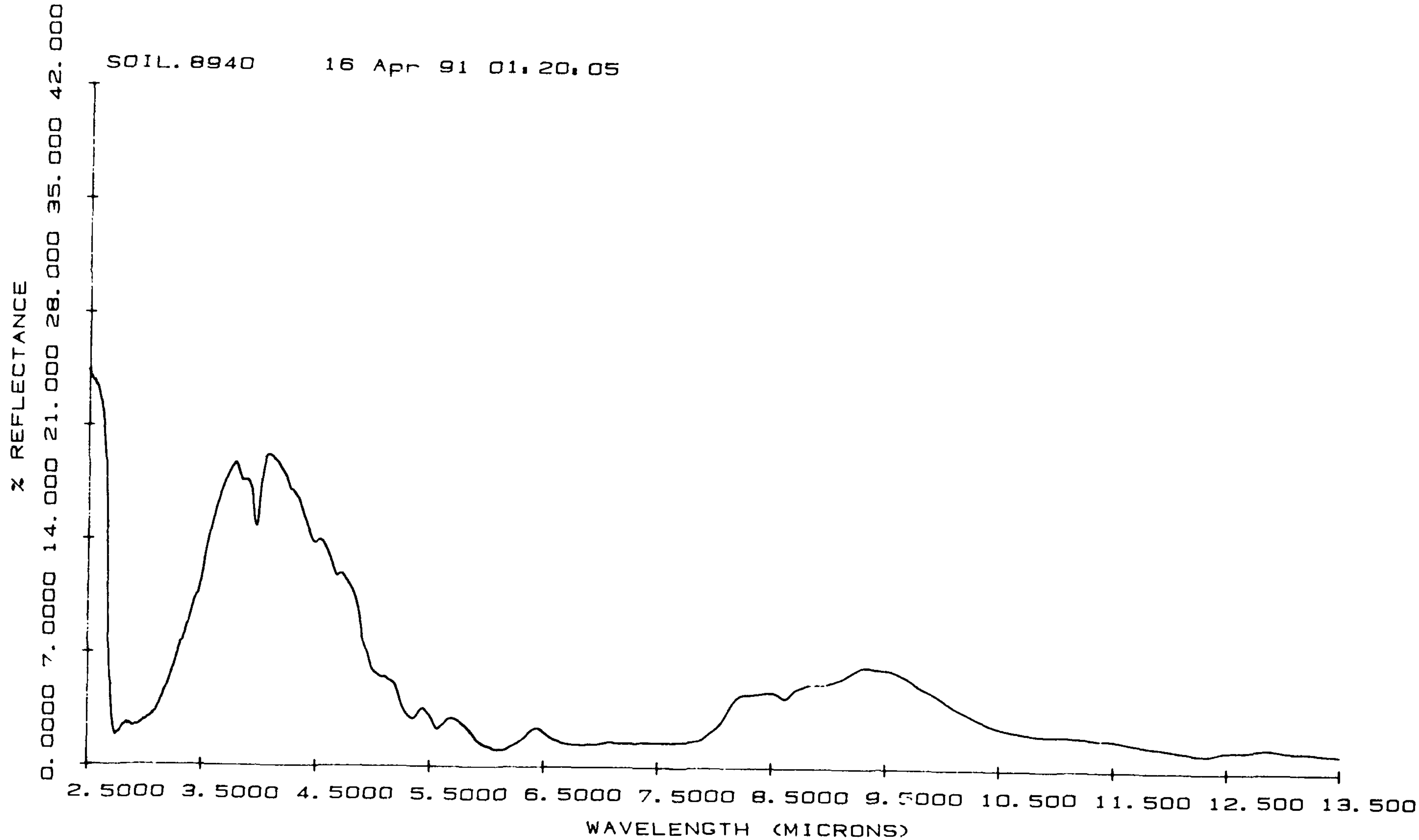
Description: This is a moderately-sorted, light-brown, fine-grained, thenarditic, subfeldspathic quartz calciclastic sand. The light-brown color is due to brown thenardite (Na-sulfate) and Na-rich plagioclase (dark gray). The thenardite is silt sized, but has weathered/flocculated into sand-sized aggregates.

XRD analysis: Sample consists of 34% calcite, 29% quartz, 23% Ca-rich plagioclase, 13% thenardite and 1% clay minerals. The clay minerals component is made up of 45% mixed-layered illite/smectite, 39% illite, 11% smectite and 5% kaolinite.

Comments: Three reflectance peaks between 8 and 10 micrometers are due to clay coated quartz grains. The maximum near 6.4 micrometers is a surface scattering calcite peak due to C-O stretching, while the deep narrow trough near 4 micrometers is due to calcite absorption. A reflectance minimum near 4.7 micrometers may be due to S-O stretching in thenardite. The broad water band at 2.9 micrometers is due to clay in the soil.

Acquistion of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL.8940 16 Apr 91 01:20:05
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-40

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Lovelock, NV. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

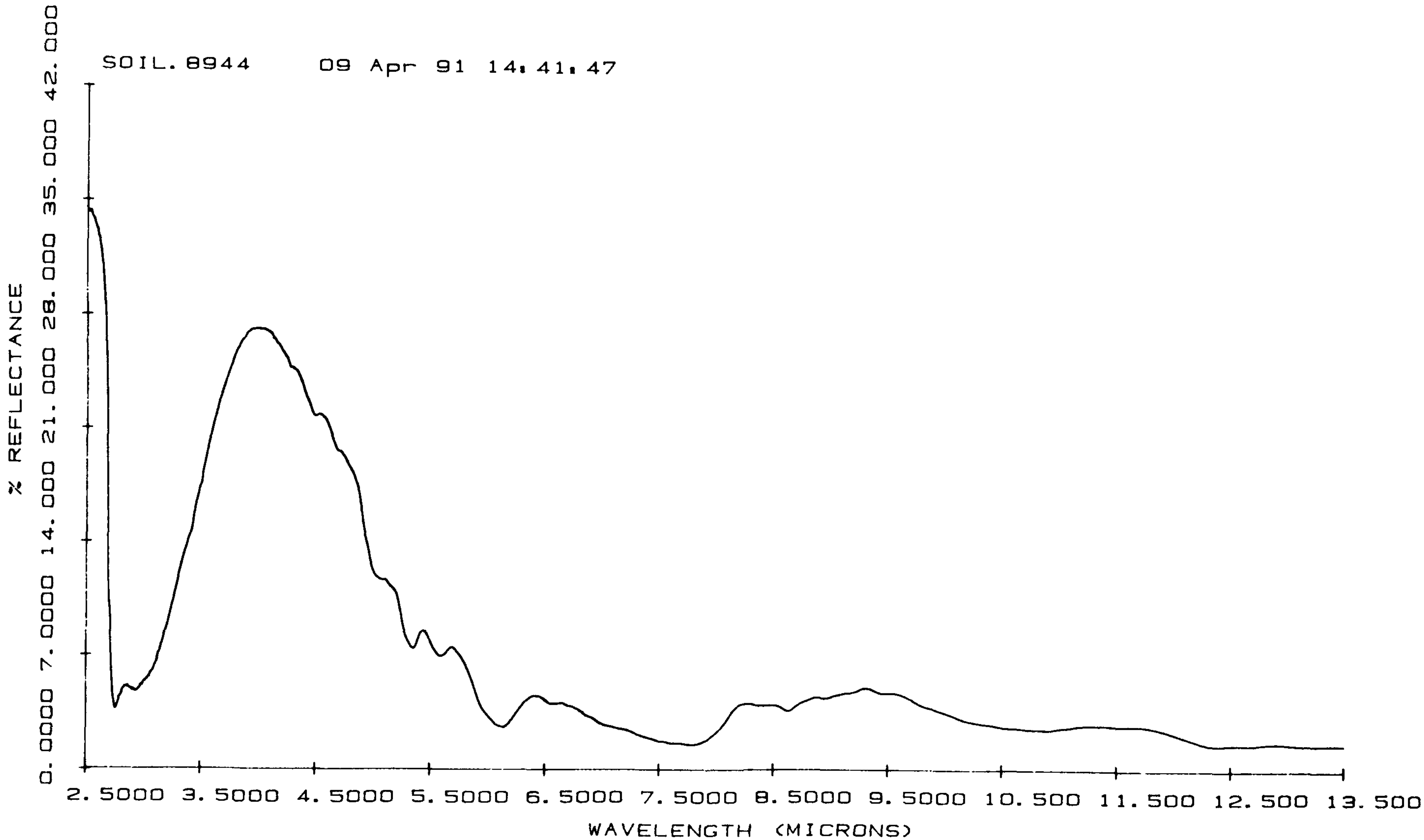
Description: This is a moderately-sorted, subangular (grain shape), brown, fine-grained micaceous calcareous feldspathic quartz sand.

XRD analysis: Sample consists of 55% quartz, 35% feldspar (microcline, orthoclase and Na-rich plagioclase. Micas total less than 5% of the sample and consist of muscovite, biotite and phlogopite. Calcite occurs as white silt-sized particles. Organic matter (twigs & rootlets) makes up less than 1% of the sample. The clays (<1%) consist of illite, mixed-layered illite/ smectite, smectite and kaolinite.

Comments: In the 8.0 to 10.5 micrometer region, the spectrum is dominated by broad silicate surface scattering due to Si-O stretching vibrations. Hydroxyl and water absorptions occur in the 2.7-2.9 micrometer region. A carbonate absorption band due to calcite occurs near 4.0 micrometers and a weak carbo-nate fundamental reflectance peak, also due to calcite, appears near 6.3 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL.8944 09 Apr 91 14:41:47
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-44

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Winnemucca, NV. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

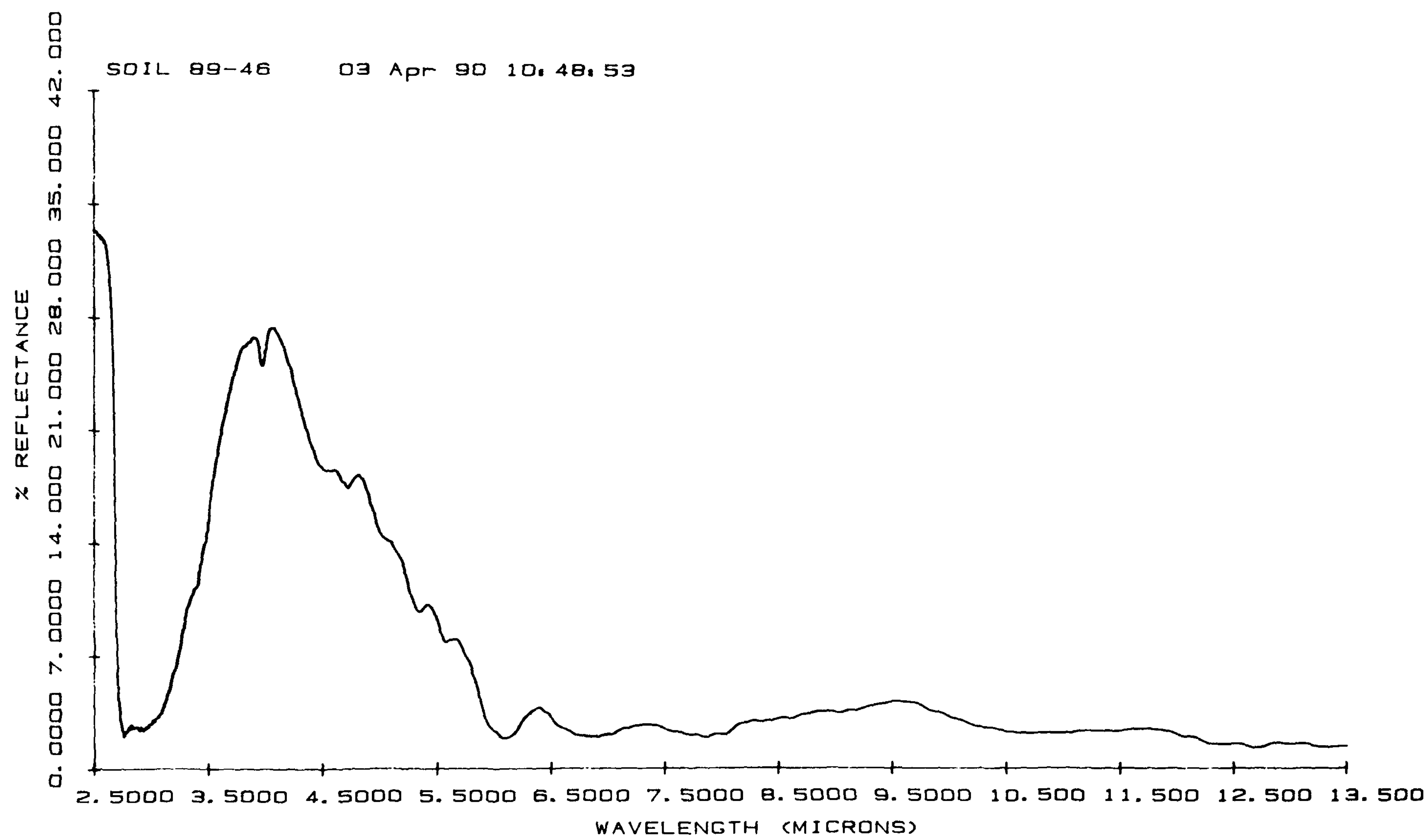
Description: This is a poorly-sorted, brown, medium-grained subfeldspathic quartz silt. This sample is dominated by silt-sized quartz but also contains dark-gray sand-sized grains of Ca-rich plagioclase.

XRD analysis: Sample consists of 79% quartz, 20% Ca-rich plagioclase and less than 0.5% clays. The clay fraction contains illite, mixed-layered illite/smectite, kaolinite and chlorite.

Comments: XRD analysis indicates a high quartz content for this sample, however fine sample particle size produces rather weak expression of spectral features in the 8 to 13.5 micrometer Si-O stretching region of the spectrum. Clay mineral hydroxyl and water bands appear in the 2.7-2.9 micrometer region.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL 89-46 03 Apr 90 10:48:53
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-46

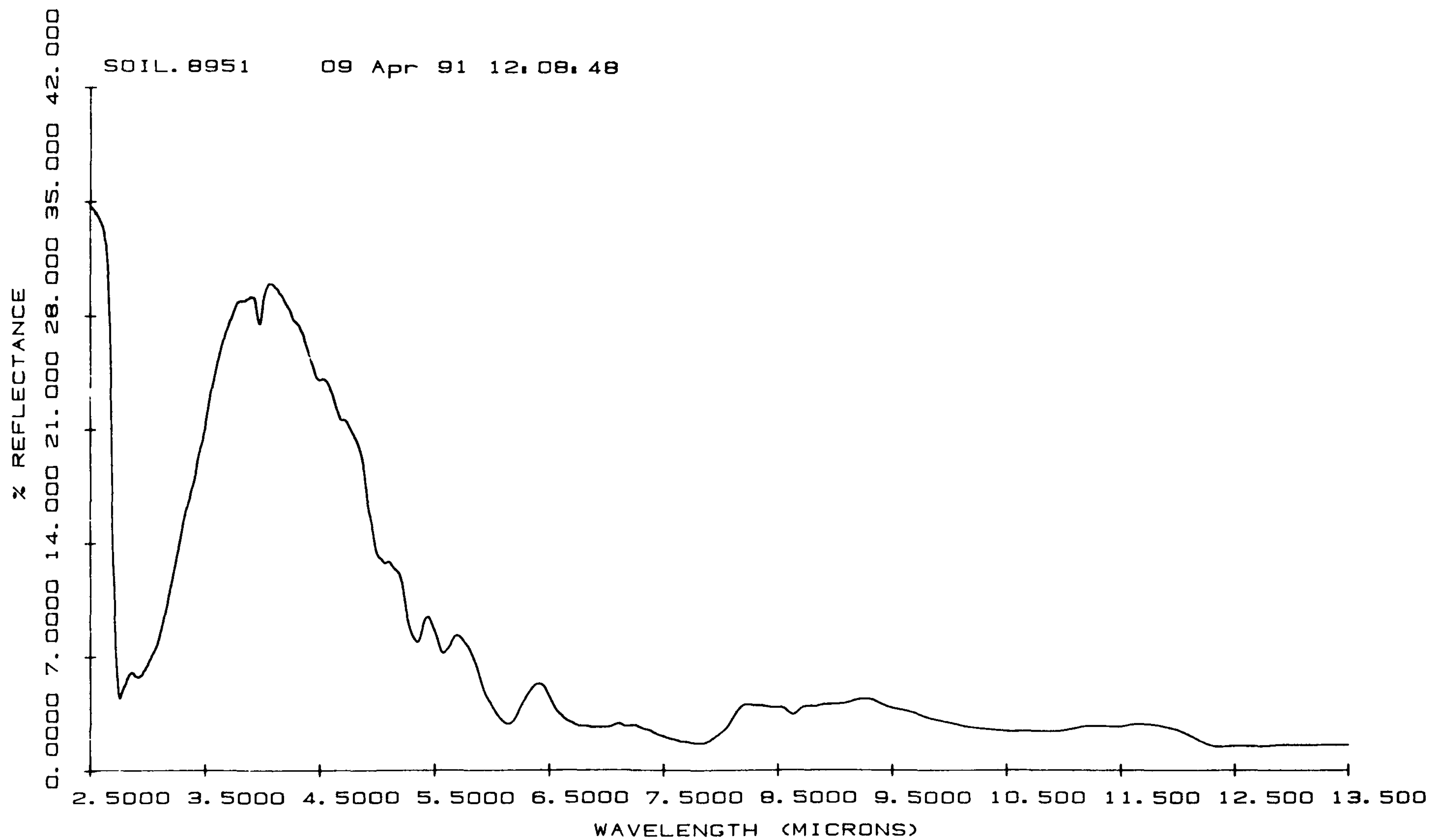
Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Winnemucca, NV. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

Description: This is a well-sorted, light-brown, fine-grained, subfeldspathic quartz silt.

XRD analysis: Sample contains 76% quartz, of which 10% is cristobalite. Feldspars consist of dark gray Na-rich plagioclase (12%) and white microcline (12%). Sample contains 6% gypsum and minor clay minerals. The clay minerals (1%) consist of mixed-layered illite/smectite, illite, smectite and kaolinite.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL.8951 09 Apr 91 12:08:48
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-51

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Battle Mountain, NV. Sample characterization and chemical/ physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

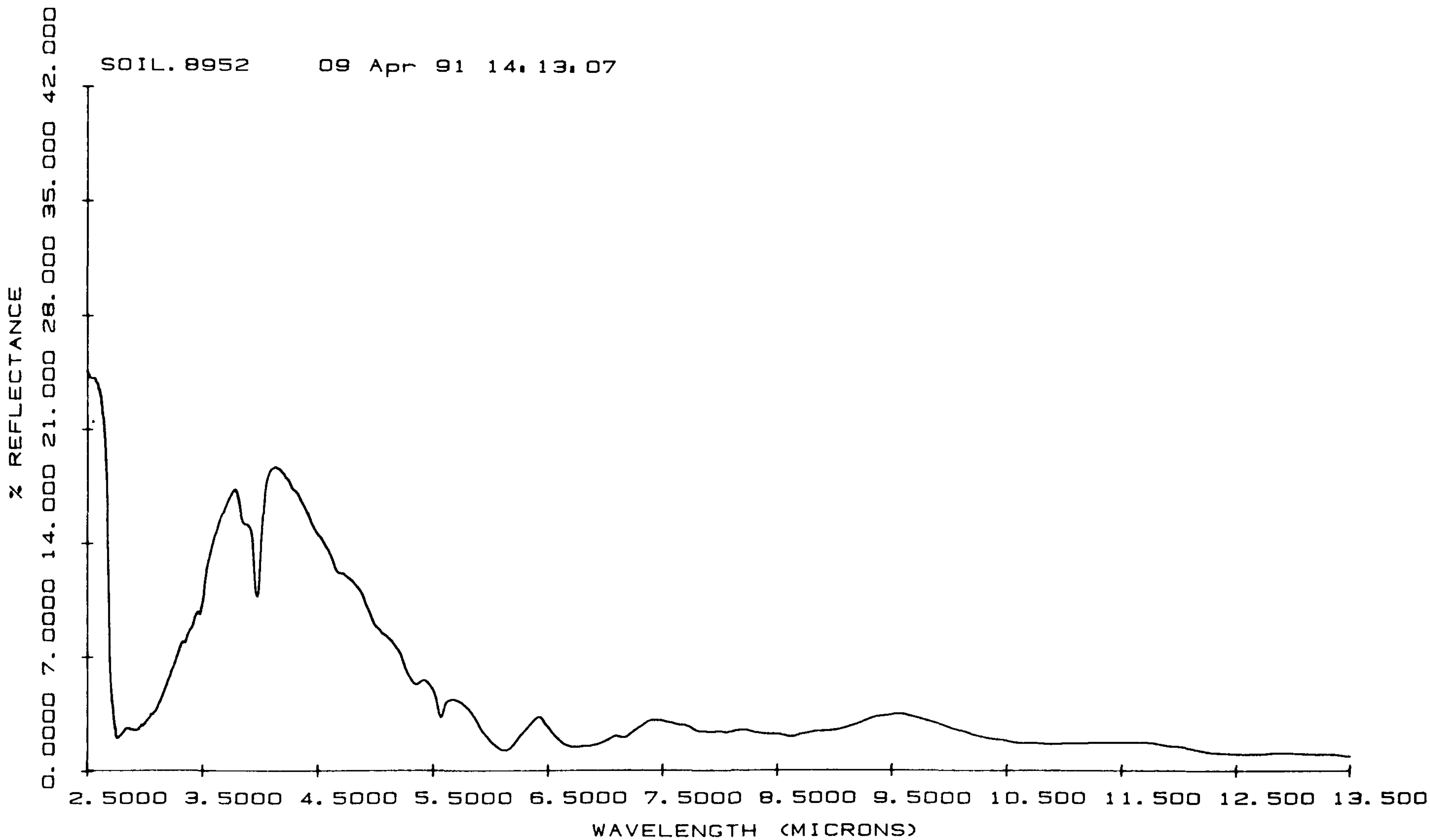
Description: This is a moderately-sorted, light-brown, sandy feldspathic quartz silt. This sample contains sand-sized grains of dark gray plagioclase and dark red to black sand-sized fragments of volcanic rock.

XRD analysis: Sample consists of 59% quartz, 17% Na-rich plagioclase, 21% microcline, 1% alunite, 1% clinoptilolite and 1% clay minerals.

Comments: XRD analysis indicates a high quartz content for this sample, however fine (silt-sized) sample particles produce low spectral contrast in the 8 to 13.5 micrometer Si-O stretching region of the spectrum. A water band at 2.9 micrometers and a sharper hydroxyl band at 2.7 micrometers are due to the small amount of clay in the soil. Although not indicated by XRD analysis, weak absorption near 4.0 micrometers and a moderately expressed reflectance peak near 6.4 micrometers indicates the presence of a small amount of carbo-nate material.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL.8952 09 Apr 91 14:13:07
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-52

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Battle Mountain, NV. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

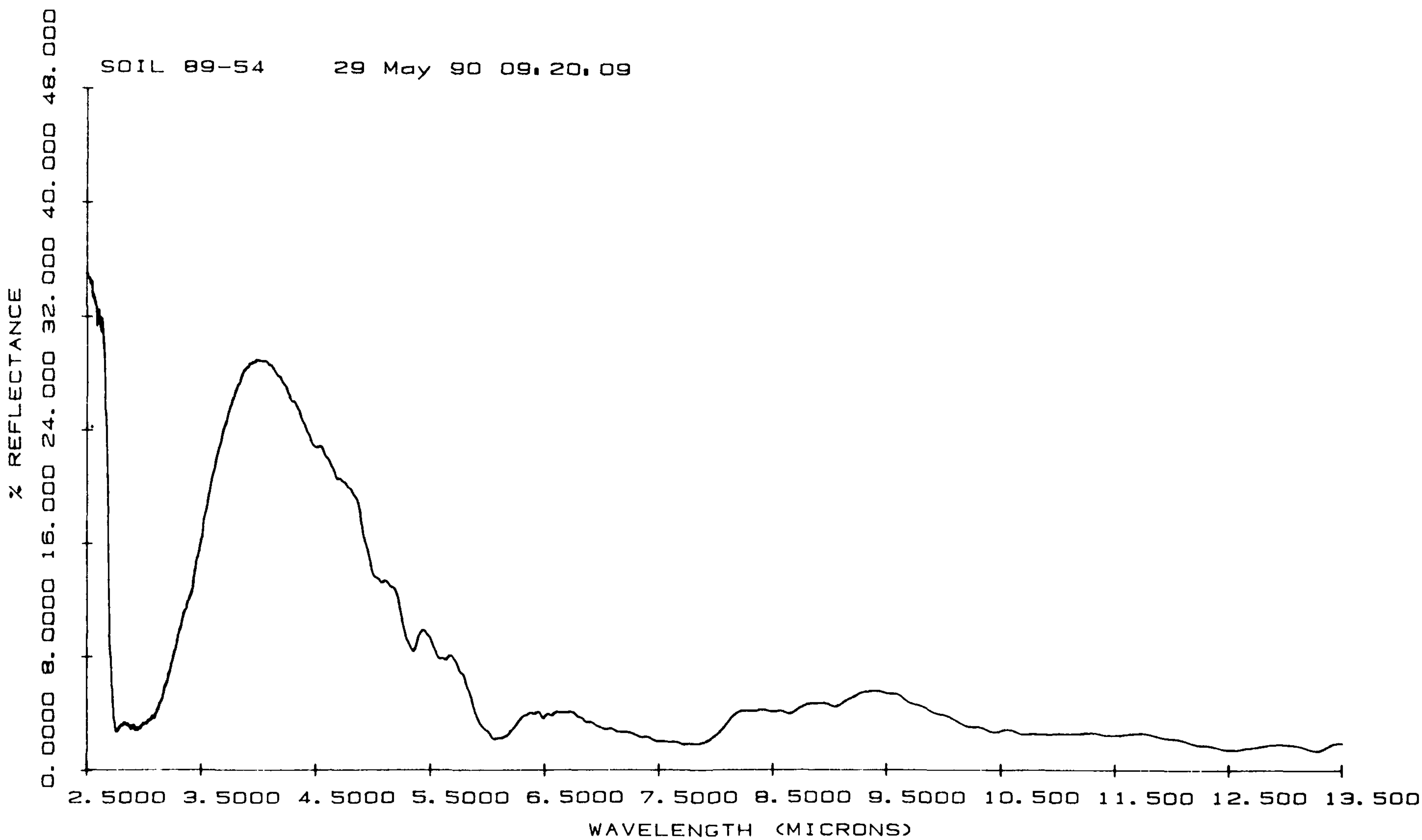
Description: This is a well-sorted, light-brown calcareous subfeldspathic quartz silt.

XRD analysis: Sample consists of 65% quartz, 18% feldspar, 16% calcite, 1% clinoptilotite (silica-rich zeolite) and <1% clay minerals. The clays consist of illite, mixed-layered clay and kaolinite.

Comments: XRD analysis indicates a high quartz content for this sample, how-ever fine sample particle size produces a moderate to low spectral contrast in the 8 to 13.5 micrometer region. Poorly resolved hydroxyl and water absorption bands appear between 2.7 and 2.9 micrometers. A sharp calcite absorption feature is present near 4.0 micrometers and the carbonate fundamental reflectance maximum is moderately expressed near 6.4 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-54
29 May 90 09:20:09
% REFLECTANCE
0.0000
8.0000
16.000
24.000
32.000
40.000
48.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: 89-54

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Battle Mountain, NV. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

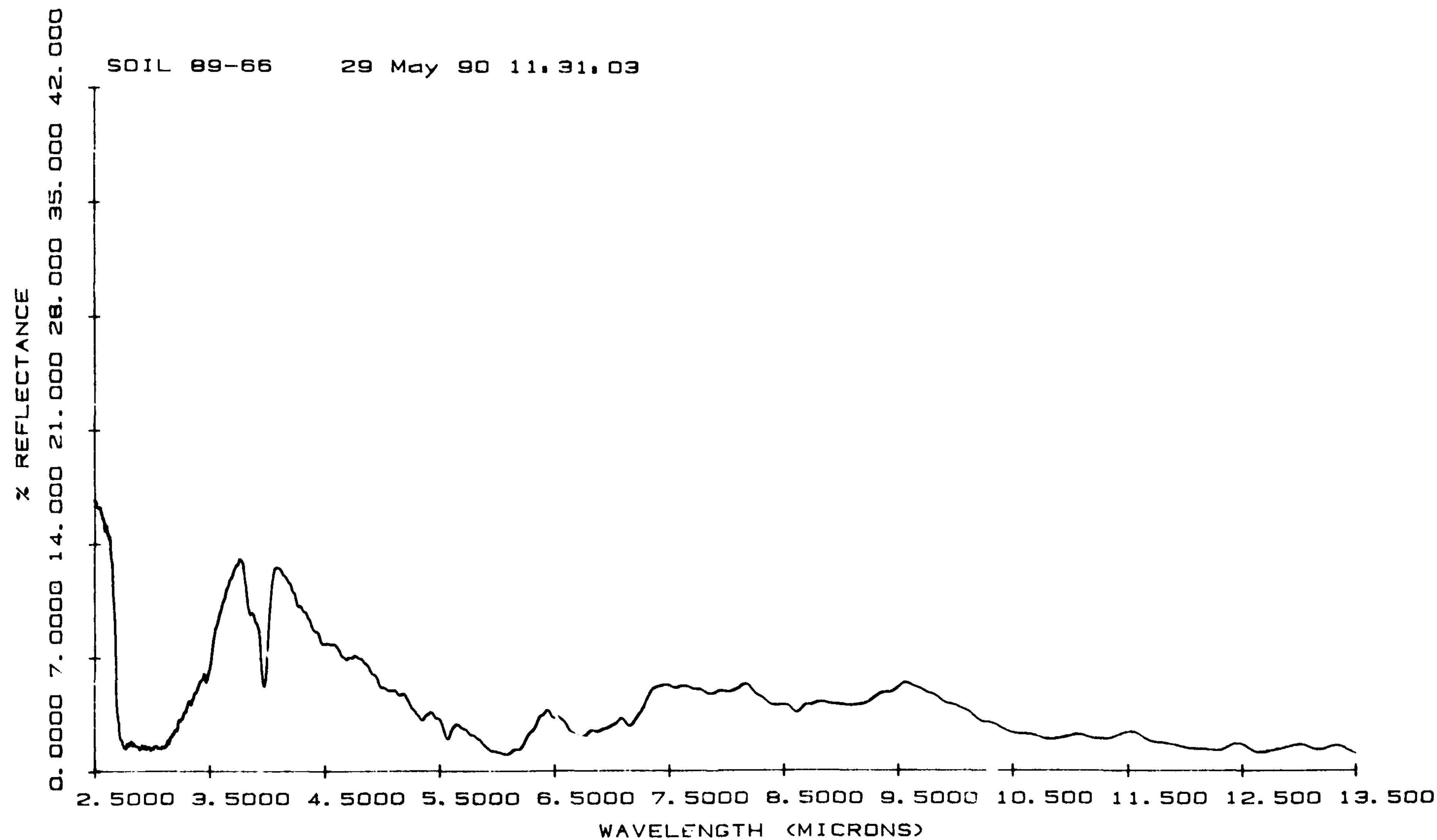
Description: This is a moderately well-sorted, brown subfeldspathic quartz silt. This sample contains 10% rootlets and twigs.

XRD analysis: Sample consists of 83% quartz and 17% feldspar (11% albite and 6% K-feldspar) plus a trace of alunite and clay minerals. The clays consist of illite, mixed-layered clay, and kaolinite.

Comments: XRD analysis indicates a high quartz content for this sample, however coating of individual quartz grains by clay minerals causes spectral features in the 8 to 13.5 micrometer region to be somewhat distorted and only moderately expressed. A water band at 2.9 micrometers and the sharper hydroxyl band at 2.7 micrometers due to OH stretching vibrations are due to the small amount of clay in the soil.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-66
29 May 90 11:31:03
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-66

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Red Lake, Jornada Experimental Range, NM. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

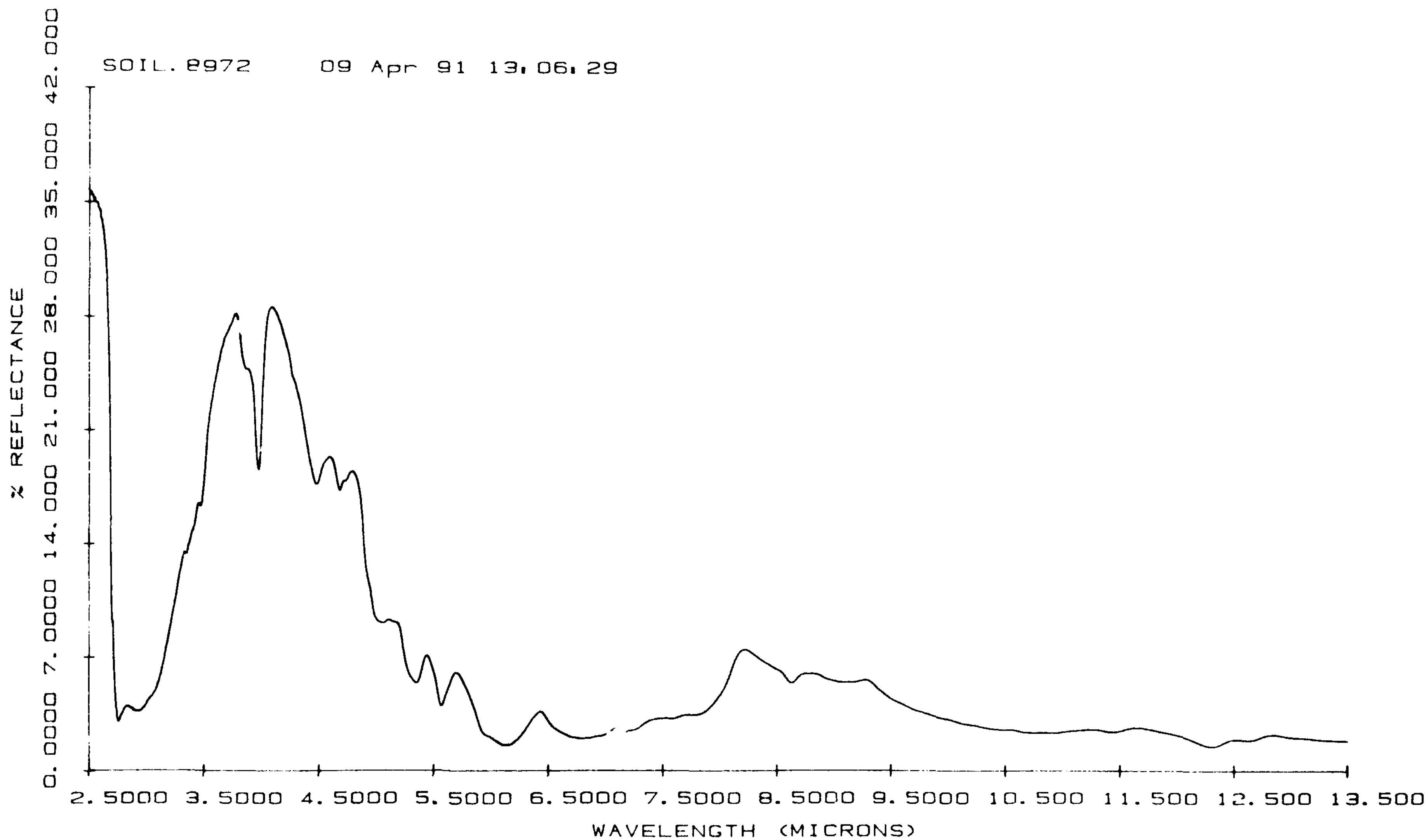
Description: This is a well-sorted, brown, calcareous subfeldspathic gypsiferous quartz silt.

XRD analysis: Sample consists of 47% quartz, 24% gypsum, 18% K-feldspar, 11% calcite and a trace of amphibole (ferromagnesium silicate) and clays. The clays consist of illite, mixed-layered clay, kaolinite and chlorite.

Comments: This spectrum exhibits hydroxyl and water absorption features between 2.7 and 2.9 micrometers. A sharp absorption band due to calcite appears near 4.0 micrometers and the carbonate fundamental occurs near 6.4 micrometers. Clay coatings on quartz grains account for the complex series of maxima between between 7.0 and 10.0 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL.8972 09 Apr 91 13:06:29
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-72

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at the Jornada Experimental Range, near Las Cruces, NM. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

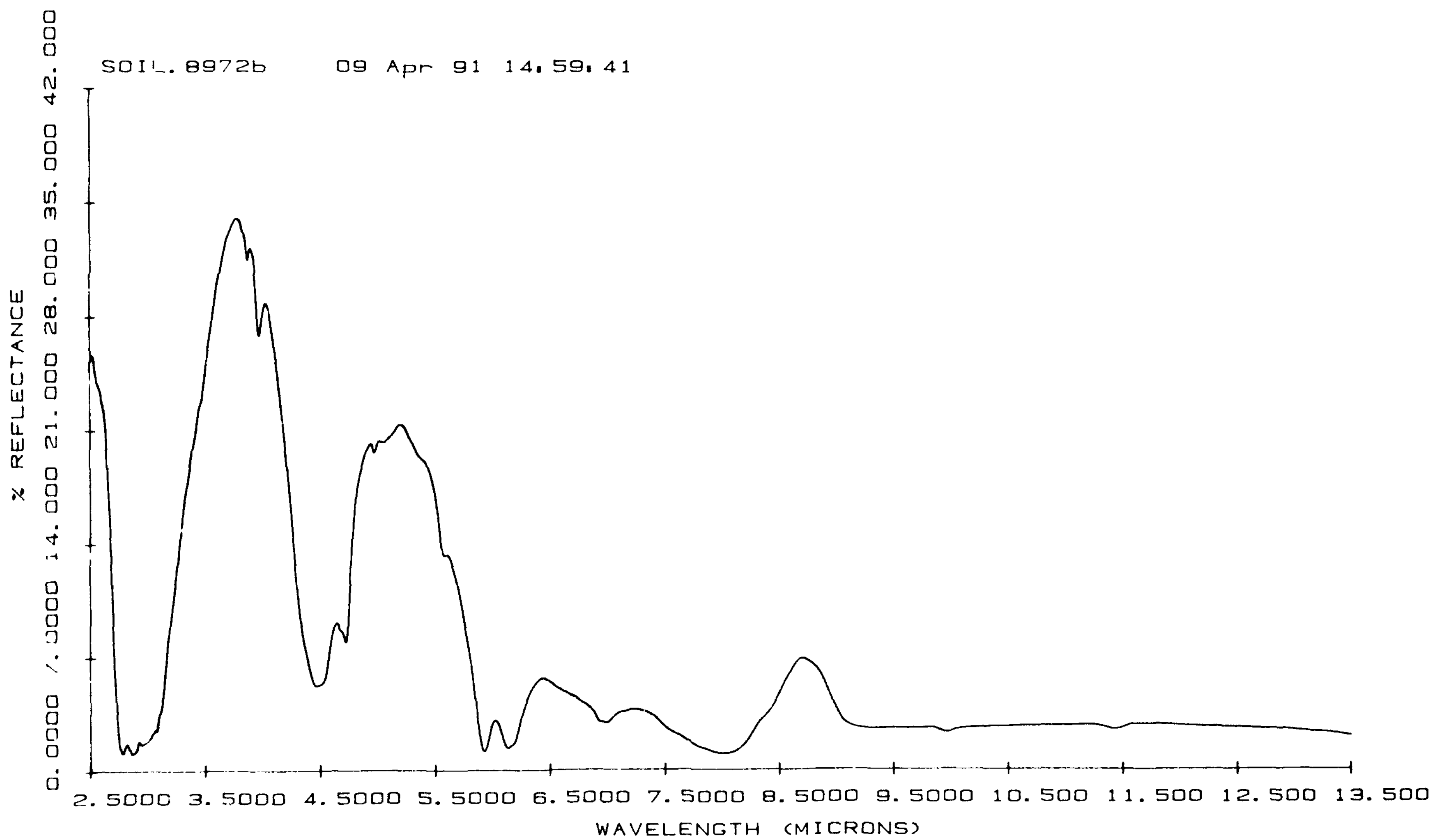
Description: This is a well-sorted, angular (grain shape), light-buff colored, very fine-grained silty sand containing quartz, feldspar, magnetite, and carbonate. The white carbonates coat the quartz grains with a thin white film.

XRD analysis: Sample consists of 84% quartz, 7% plagioclase (albite), 4% calcite, 3% dolomite, 2% gypsum and a trace of clay minerals.

Comments: XRD analysis indicates a high quartz content for this sample, however fine sample particle size causes features in the 8-13 micrometer Si-O stretching region to be only moderately expressed. Calcite absorption occurs near 4.0 micrometers and the carbonate stretching fundamental appears near 6.4 micrometers. Clay hydroxyl and water absorptions dominate the spectrum between 2.7 and 2.9 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL.8972b 09 Apr 91 14:59:41
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-72B

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Jornada Experimental Range, near Las Cruces, NM. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

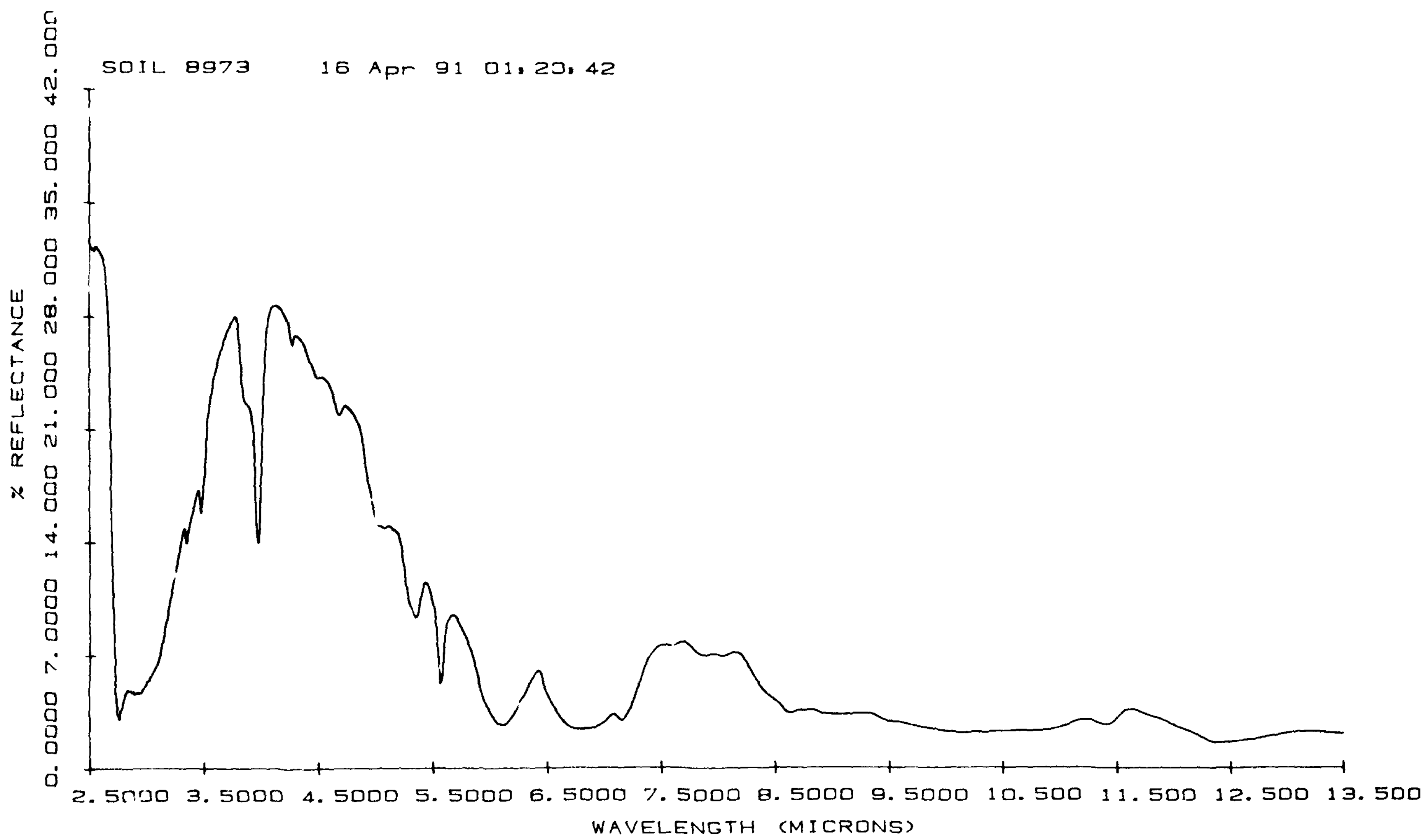
Description: This is a very well-sorted, white, dolomitic gypsiferous silt.

XRD analysis: Sample consists of 36% gypsum, 31% dolomite, 19% calcite, 11% quartz, 3% plagioclase (albite) and a trace of kaolinite. A significant amount of NaCl is also indicated.

Comments: Gypsum features dominate the spectrum. Absorptions due to moisture and gypsum water of hydration occur in the vicinity of 2.9 micrometers. The gypsum sulfate fundamental is moderately expressed near 8.7 micrometers. A very weak calcite absorption appears near 4.0 micrometers and a moderate reflectance peak, also due to calcite, appears near 6.3 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboracries, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL 8973   16 Apr 91 01:23:42
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-73

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Point of Rox near the Jornada Experimental Range NM. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

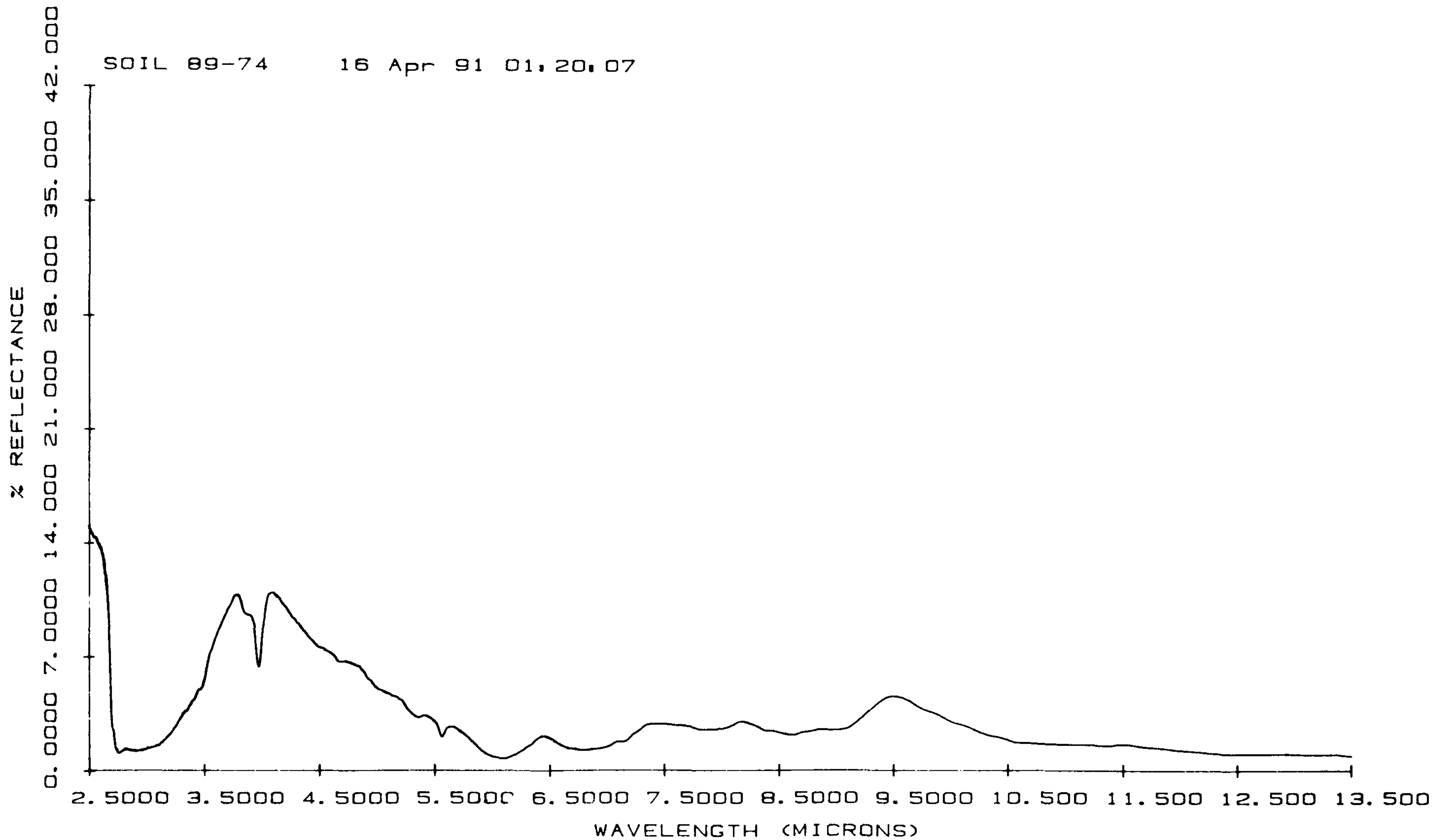
Description: This is a well sorted, dark orangish-brown, very fine-grained calcareous quartz silt.

XRD analysis: Sample consists of 75% quartz, 19% calcite, 5% K-feldspar and 1% clay minerals. The orangish-brown color is due to hematite coating the individual silt grains. The clay minerals consist of illite, chlorite, mixed layered clay and kaolinite.

Comments: Bands due to hydroxyl and water absorption appear at 2.7 and 2.9 micrometers respectively. A strong calcite absorption feature appears near 4.0 micrometers and a surface scattering maximum, also due to calcite, occurs near 6.3 micrometers. A distorted feature due mainly to Si-O absorption in quartz appears between about 7.0 and 8.6 micrometers. Feature distortion is most likely due to coating of quartz grairs by other species, e.g. clay minerals.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-74
16 Apr 91 01:20:07
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.500C
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 8 -74

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Old Coe Lake near Ft. Bliss, Texas. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

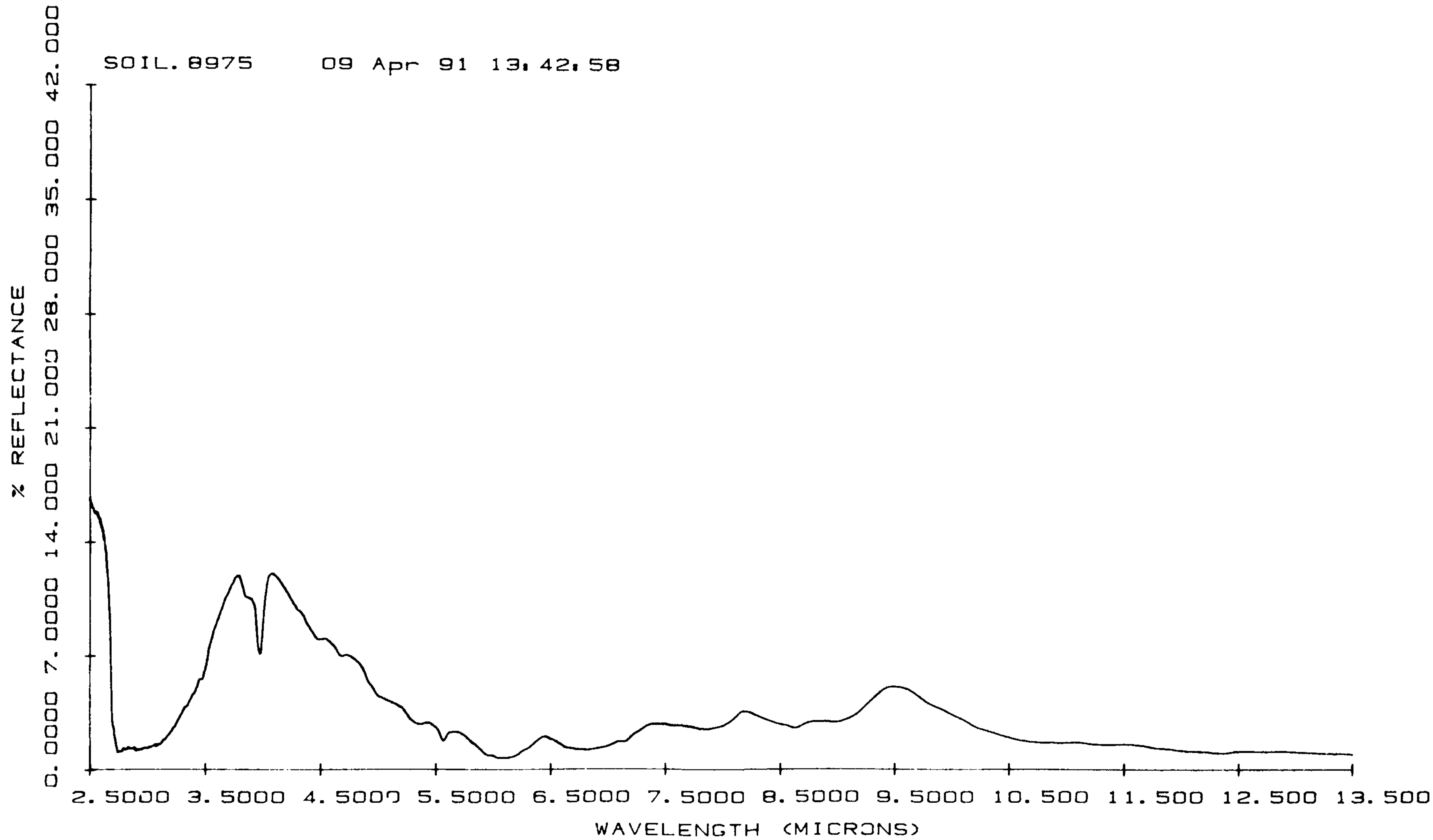
Description: This is a well-sorted, dark brown calcareous quartz silt.

XRD analysis: Sample consists of 78% quartz, 21% calcite and 1% clay min-erals. The clays contain mixed-layered illite/smectite, smectite, illite and kaolinite. This sample contains approximately 2% organic matter (twigs and rootlets).

Comments: Three moderately expressed maxima between 8.0 and 10.0 micrometers constitute a quartz doublet significantly distorted by clay minerals, the latter producing the somewhat stronger reflectance peak observed at 9.5 micrometers. The water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to the clay in the soil. Calcite absorption appears near 4.0 micrometers, while a calcite reflectance maximum occurs near 6.4 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL.8975
09 Apr 91 13:42:58
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-75

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Old Coe Lake near Ft. Bliss, TX. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

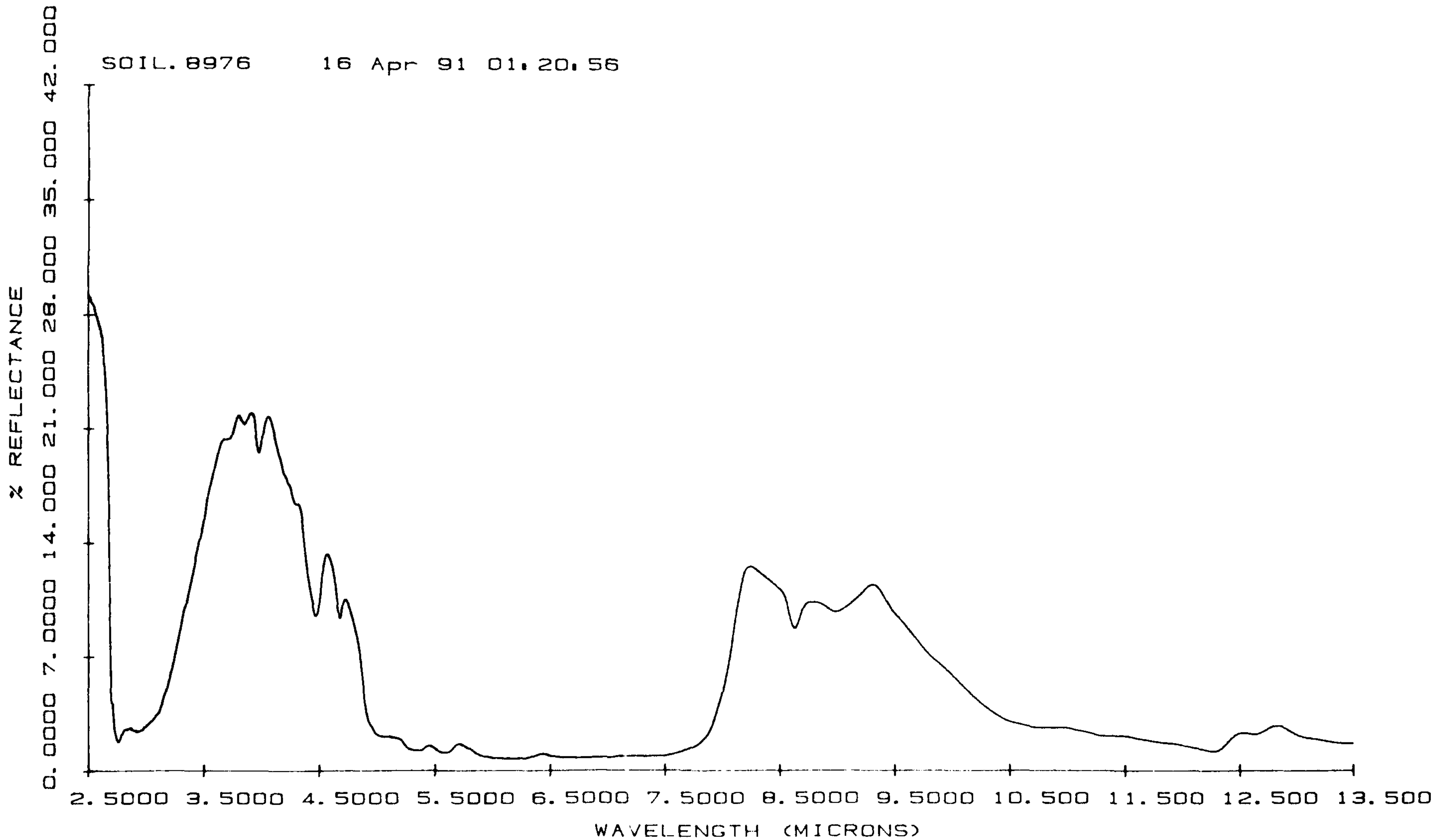
Description: This is a well-sorted, dark-brown, calcareous subfeldspathic quartz silt.

XRD analysis: Sample consists of 85% quartz, 8% feldspar (5% K-feldspar, 3 % plagioclase), 7% calcite and a trace of clay-sized particles. The clays con-sist of illite, mixed-layered illite/smectite, smectite and kaolinite.

Comments: Hydroxyl and water bands appear in the 2.7-2.9 micrometer region. Absorption due to calcite appears near 4.0 micrometers and surface scattering by calcite occurs near 6.3 micrometers. A broad distorted doublet between 8.0 and 10.0 micrometers is due to quartz. The distortion is most likely due to coatings of other species, e.g. clay minerals, on the individual quartz grains.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL.8976 16 Apr 91 01:20:56
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-76

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Mcgregor Range, Ft. Bliss, TX. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

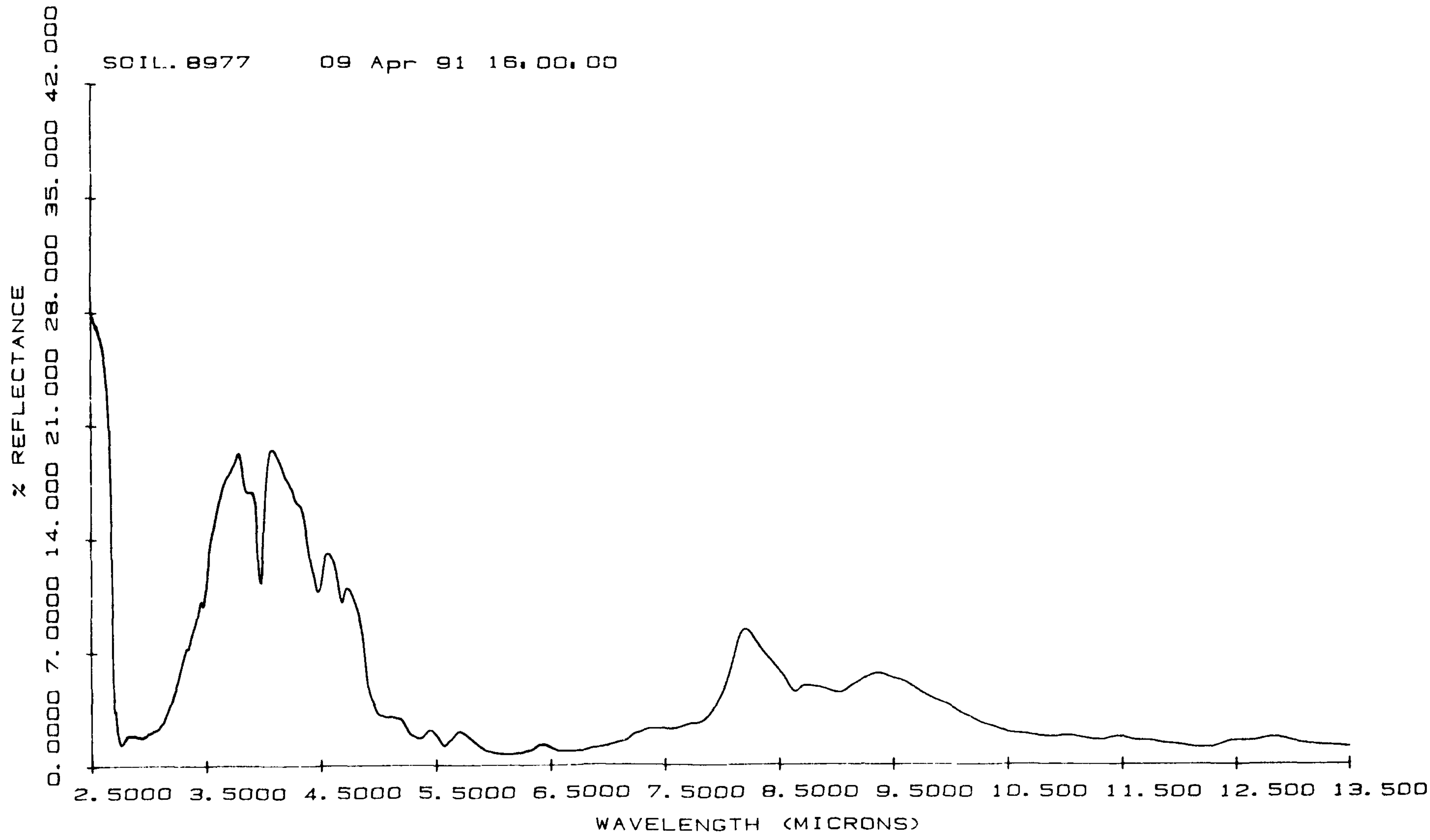
Description: This is a well-sorted, subangular (grain shape), light-orange, medium-grained sand dominated by quartz, feldspar, and sandstone rock fragments (minor). The light-orange color is due to a thin hematite coating on the quartz grains.

XRD analysis: Sample consists of 92% quartz, 7% feldspar (anorthoclase, orthoclase) and 1% calcite.

Comments: Spectral features of quartz dominate the 8 to 13 micrometer wave-length region. The broad feature between 8 and 9.5 micrometers is particularly diagnostic of quartz, even though it shape is somewhat distorted. Weak calcite absorption appears near 4.0 micrometers and a very weak reflectance peak, also due to calcite, occur near 6.3 micrometers. Hydroxyl and water bands due to the presence of a small amount of clay minerals occur in the 2.7-2.9 micrometer region.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


SOIL..8977 09 Apr 91 16:00:00
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-77

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Mcgregor Range, Ft. Bliss,TX. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

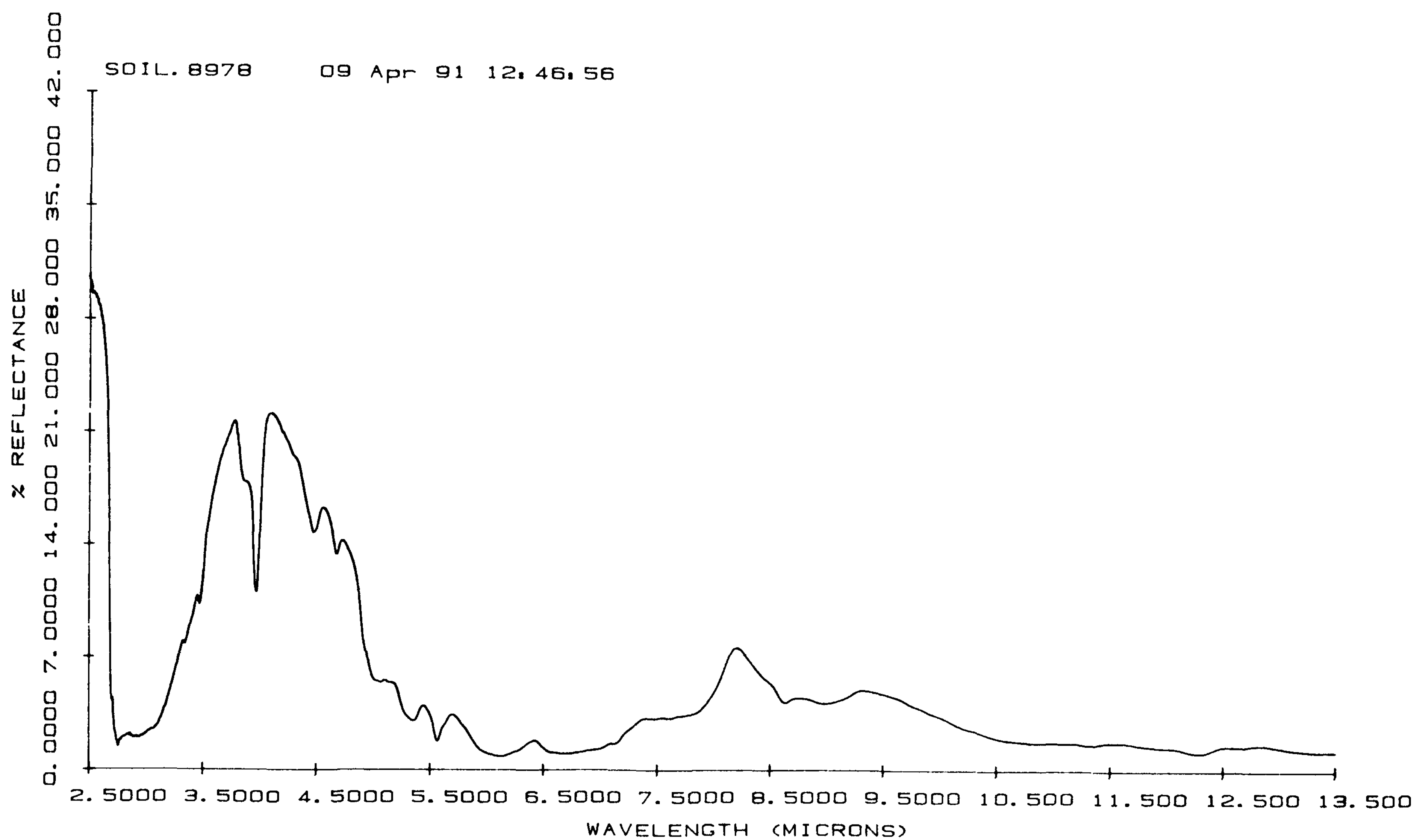
Description: This is a moderately-sorted subrounded (grain shape), light orangish-brown, medium-grained sand containing quartz, feldspar/plagioclase (white, pink, light gray) and sandstone rock fragments (20%). The light orangish-brown color is due to hematite coating the quartz grains.

XRD analysis: Sample consists of 78% quartz, 18% plagioclase (gray labradorite), 2% calcite and 2% Mg-calcite.

Comments: A somewhat distorted feature of quartz dominates the spectrum between 7.5 and 10.0 micrometers. Carbonate absorption occurs near 4.0 micrometers and the calcite carbonate fundamental is very weakly expressed near 6.4 micrometers. Hyroxyl and water bands occur in the 2.7-2.9 micrometer region.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL. 8978
09 Apr 91 12: 46: 56
% REFLECTANCE
0. 0000
7. 0000
14. 000
21. 000
28. 000
35. 000
42. 000
2. 5000
3. 5000
4. 5000
5. 5000
6. 5000
7. 5000
8. 5000
9. 5000
10. 500
11. 500
12. 500
13. 500
WAVELENGTH (MICRONS)

Sample: Soil 89-78

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley at Mcgregor Range, Ft. Bliss, TX. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

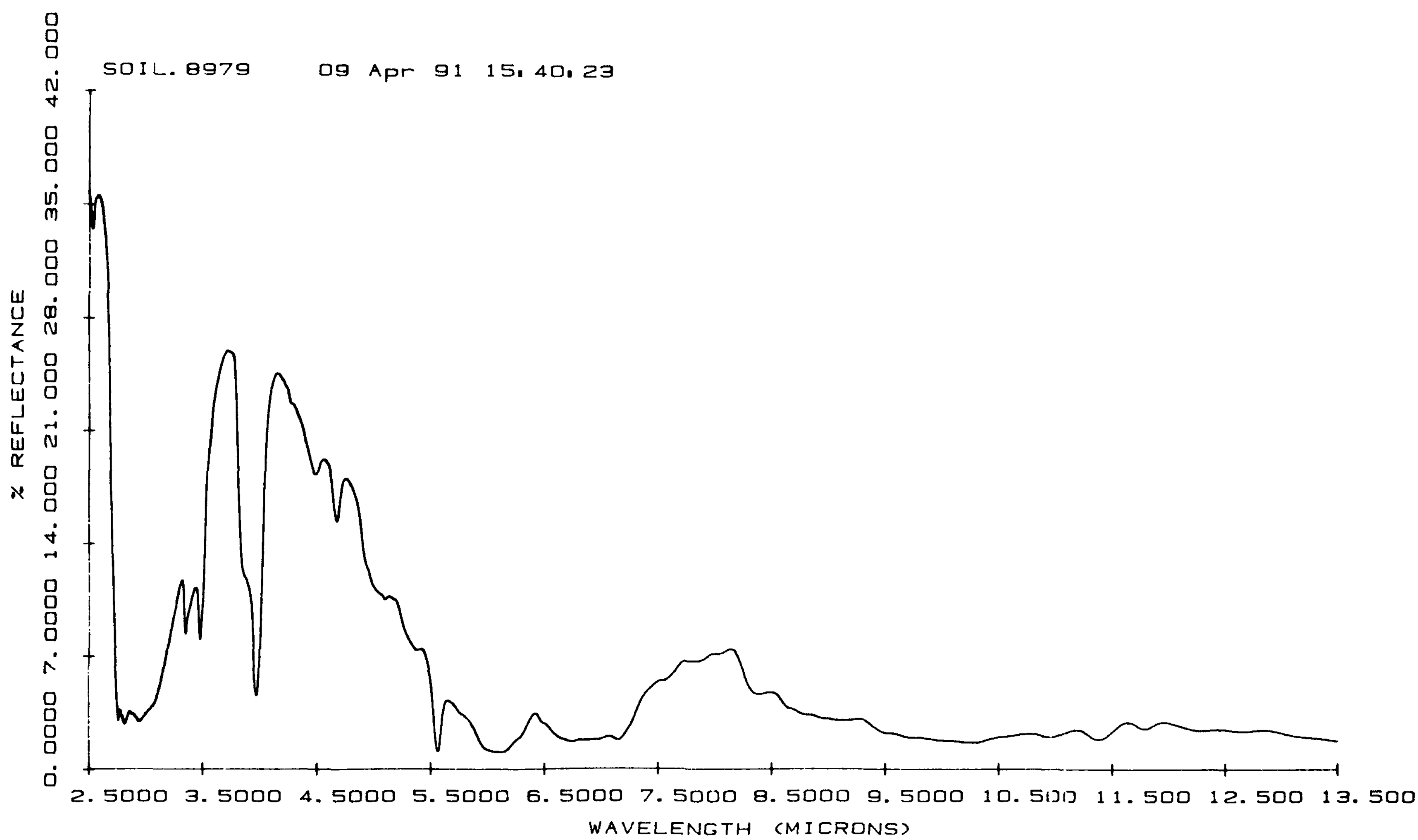
Description: This is a moderately-sorted, subangular (grain shape), light orangish-brown, fine-grained, sandstone lithic quartz sand containing 25% rock fragments. The orangish color is due to a thin hematite coating on the otherwise clear vitreous quartz grains.

XRD analysis: Sample consists of 76% quartz, 17% feldspar/plagioclase (orthoclase, oligoclase), 7% calcite and a trace of clay minerals.

Comments: Quartz dominates the spectral region above 8 micrometers. The characteristic quartz doublet between 8 and 9.5 micrometers is distorted by clay coatings. Carbonate absorption occurs near 4.0 micrometers and the carbonate fundamental is very weakly expressed at 6.4 micrometers. Hydroxyl and water bands occur between 2.7 and 2.9 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL.8979
09 Apr 91 15:40:23
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-79

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Mcgregor Range, Ft. Bliss, TX. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

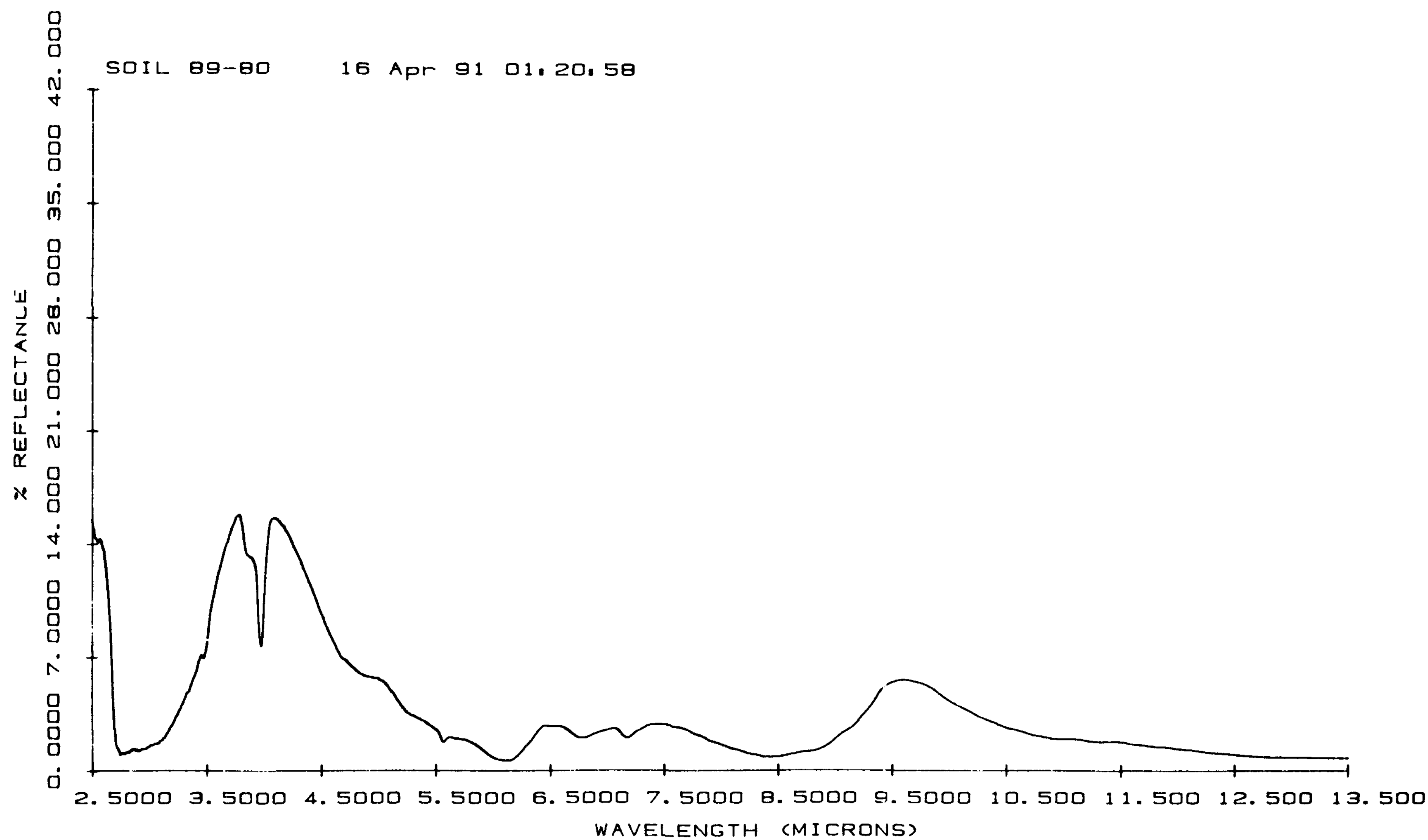
Description: This is a moderately-sorted, subangular (grain shape), white, fine-grained calcareous quartz sand. The white color is due to a thin calcite coating on the quartz grains.

XRD analysis: Sample consists of 69% quartz, 22% calcite, 9% plagioclase (albite) and a trace of halite and clay minerals. The clay component consists of illite, mixed-layered illite/smectite and kaolinite.

Comments: XRD analysis indicates a high quartz content for this sample, however fine sample particle size results in moderate spectral contrast in the 8 to 13.5 micrometer region. Calcite absorption appears near 4.0 micrometers and the carbonate fundamenal, also due to calcite, occurs near 6.4 micrometers. Hydroxyl and water bands appear between 2.7 and 2.9 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: Petrographic Analysis of Soil Surface Samples, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL 89-80 16 Apr 91 01:20:58
% REFLECTANLE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil 89-80

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near Rainbow Basin, CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

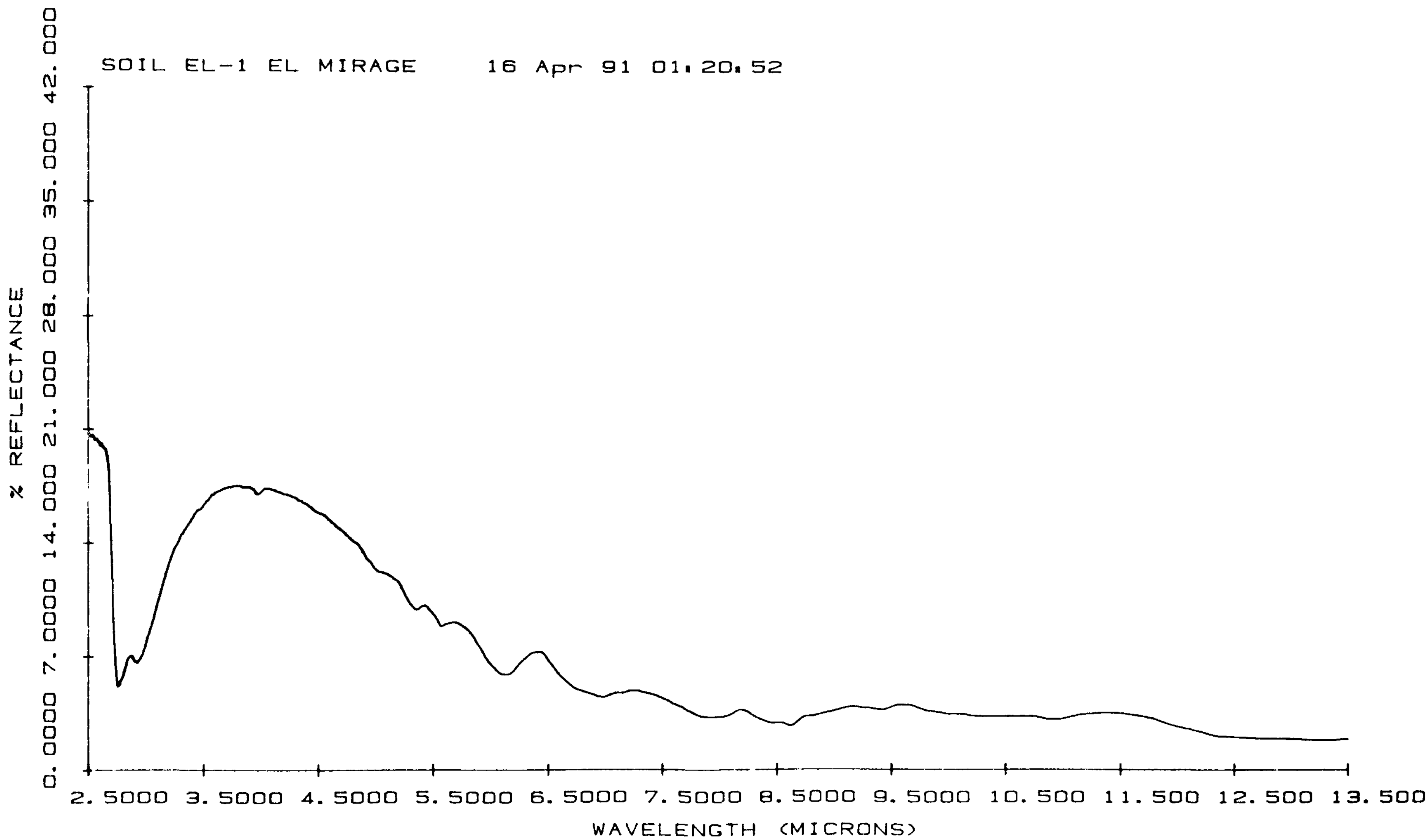
Description: This is a light-bluish mud comprised of 2/3 silt and 1/3 clay sized particles.

XRD analysis: Sample consists of 38% quartz, 26% calcite, 26% zeolite (analcime), 5% Mg-calcite, 2% feldspar (microcline) and 3% clay minerals.
The clay component consists of illite and mixed-layered illite/smectite.
This classifies the sample as a calcareous analcime quartz mud.

Comments: XRD analysis indicates a relatively high quartz content for this sample, however a combination of fine particle size (silt and clay size) and coating of quartz grains by smaller clay mineral particles has caused the diagnostic quartz doublet to be replaced by a clay mineral feature near 9.6 micrometers. The broad water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are also due to the presence of clay minerals.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.



SOIL EL-1 EL MIRAGE 16 Apr 91 01:20:52
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Soil EL-1

Sample data: Sample collected during 1989 by M. B. Satterwhite and J. P. Henley near El Mirage playa, San Bernardino County, CA. Sample characterization and chemical/physical analyses performed under contract with P. R. Luttrell, Consulting Geologist, 436 Shonto Trail, Flagstaff, AZ 86001.

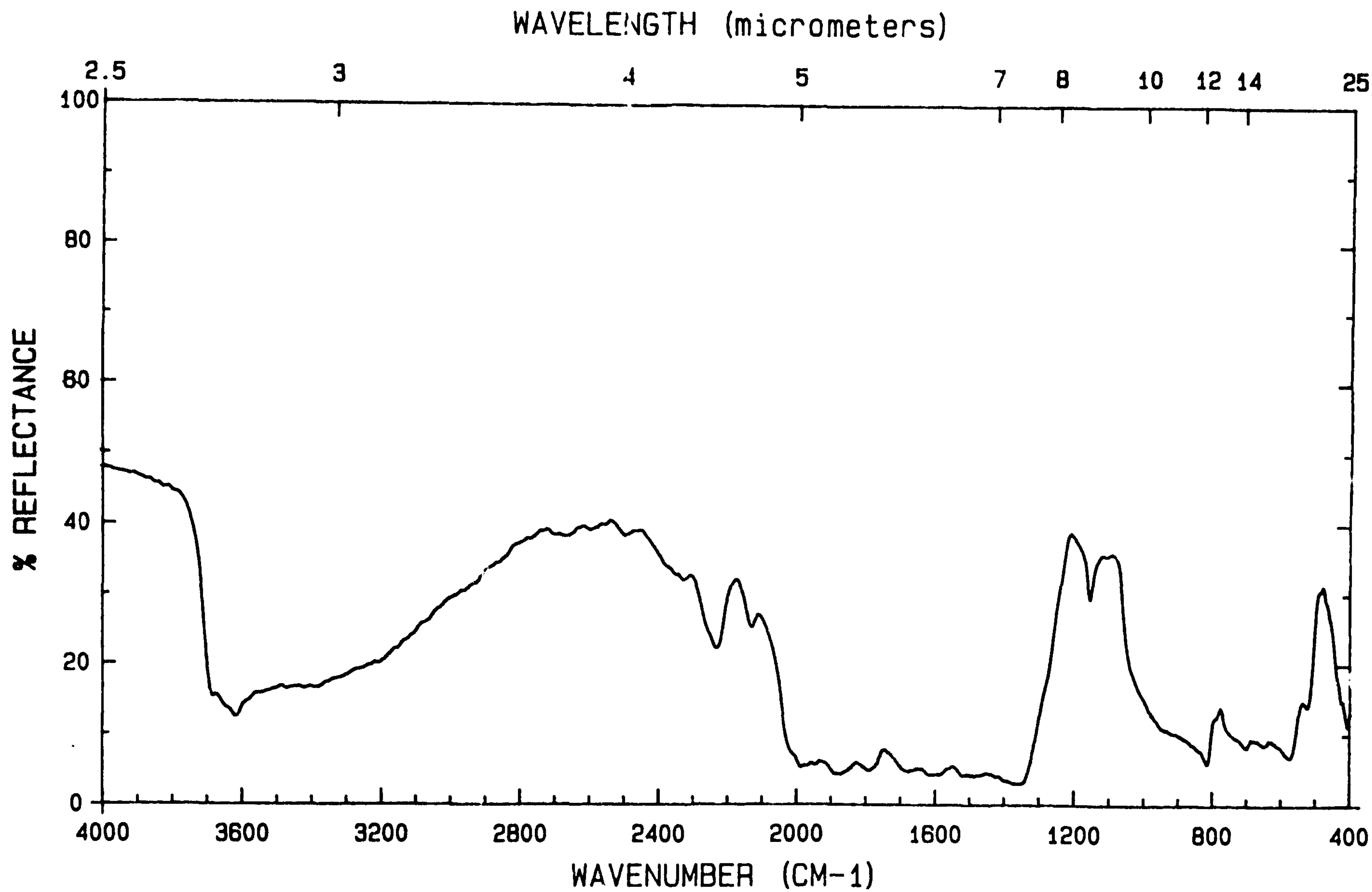
Description: This is a moderately-sorted, subangular (grain shape), light bluish-gray subfeldspathic quartz silt containing quartz, albite, calcite, magnetite and riebeckite (identified by XRD analysis). The bluish-gray color of this sample is due to the presence of riebeckite, a blue mineral of the amphibole group.

XRD analysis: Sample consists of 70% quartz, 20% plagioclase (albite), 8% calcite, 2% clays and a trace of riebeckite. The clay component contains mixed-layered chlorite/smectite, illite, chlorite, kaolinite and mixed-layered illite/smectite.

Comments: Although XRD analysis indicates a high quartz content for this sample, fine sample particle size results in low spectral contrast in the 8 to 13.5 micrometer Si-O stretching region of the spectrum. Hydroxyl absorption due to the presence of clay minerals appears at 2.7 micrometers, and a water band occurs at 2.9 micrometers. Surficial scattering due to calcite occurs near 6.3 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

Reference: <u>Petrographic Analysis of Soil Surface Samples</u>, A report prepared for U.S. Army Engineer Topographic Laboraories, Ft. Belvoir, VA by P. Rubick Luttrell, November, 1989.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
% REFLECTANCE
100
80
60
40
20
0
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #1

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

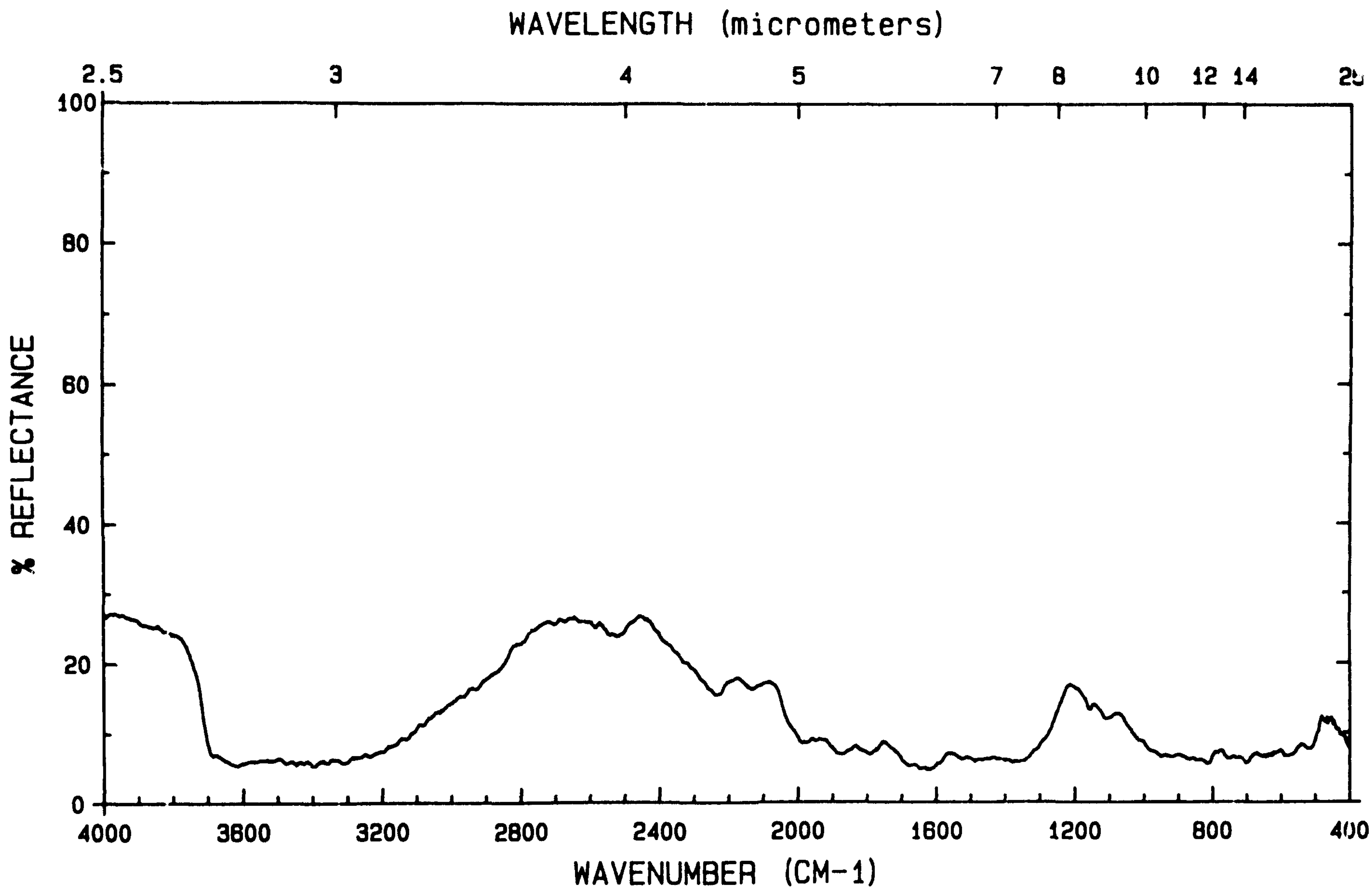
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #1

Origin: Egypt/Sudan border

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is predominantly a silicate material dominated by quartz which yields a strong reflectance maximum, due to Si-O stretching, centered at 8.6 micrometers accompanied by a weaker doublet at 12.6 micrometers. The broad water band near 2.9 micrometers and the sharper hydroxyl band near 2.7 micrometers stem from small amounts of clay and/or small inclusions of water.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #2

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

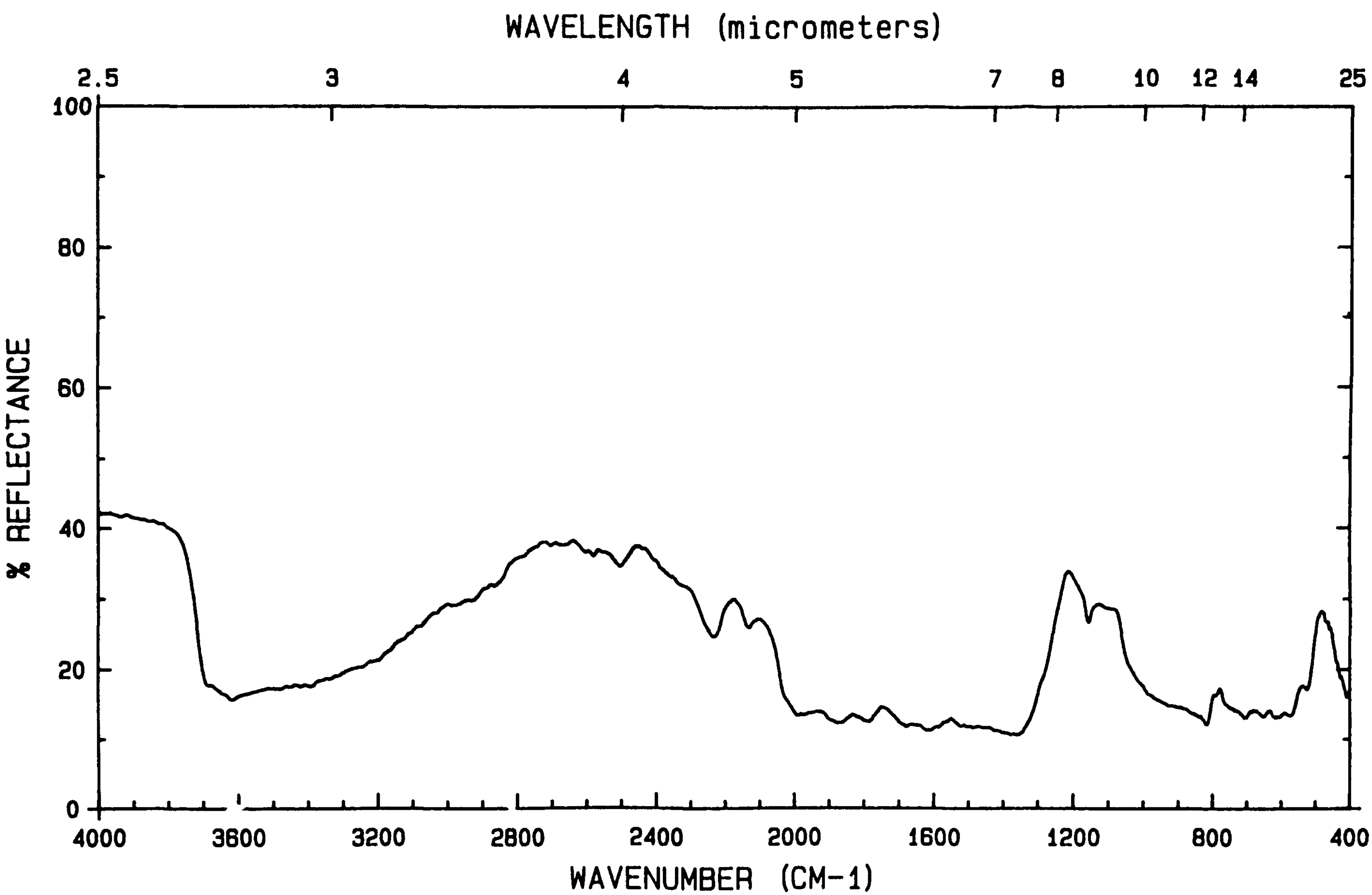
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #2

Origin: Qattaras depression in NW Egypt

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is predominantly a silicate material with a considerable amount of quartz as evidenced by strong Si-O asymmetrical stretching vibrations near 8.6 micrometers and a weak doublet due to symmetrical Si-O stretching vibration near 12.6 micrometers. A weak maximum near 6.3 micrometers together with a small reflectance trough near 4 micrometers indicates the presence of a small amount of calcite. The broad water band near 2.9 micrometers and the sharp hudroxyl band at 2.7 micrometers due to O-H stretching are due to small amounts of clay in the soil. Clay coated quartz grains account for the distortion of the quartz feature at 8.6 micrometers.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
% REFLECTANCE
100
80
60
40
20
0
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #3

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

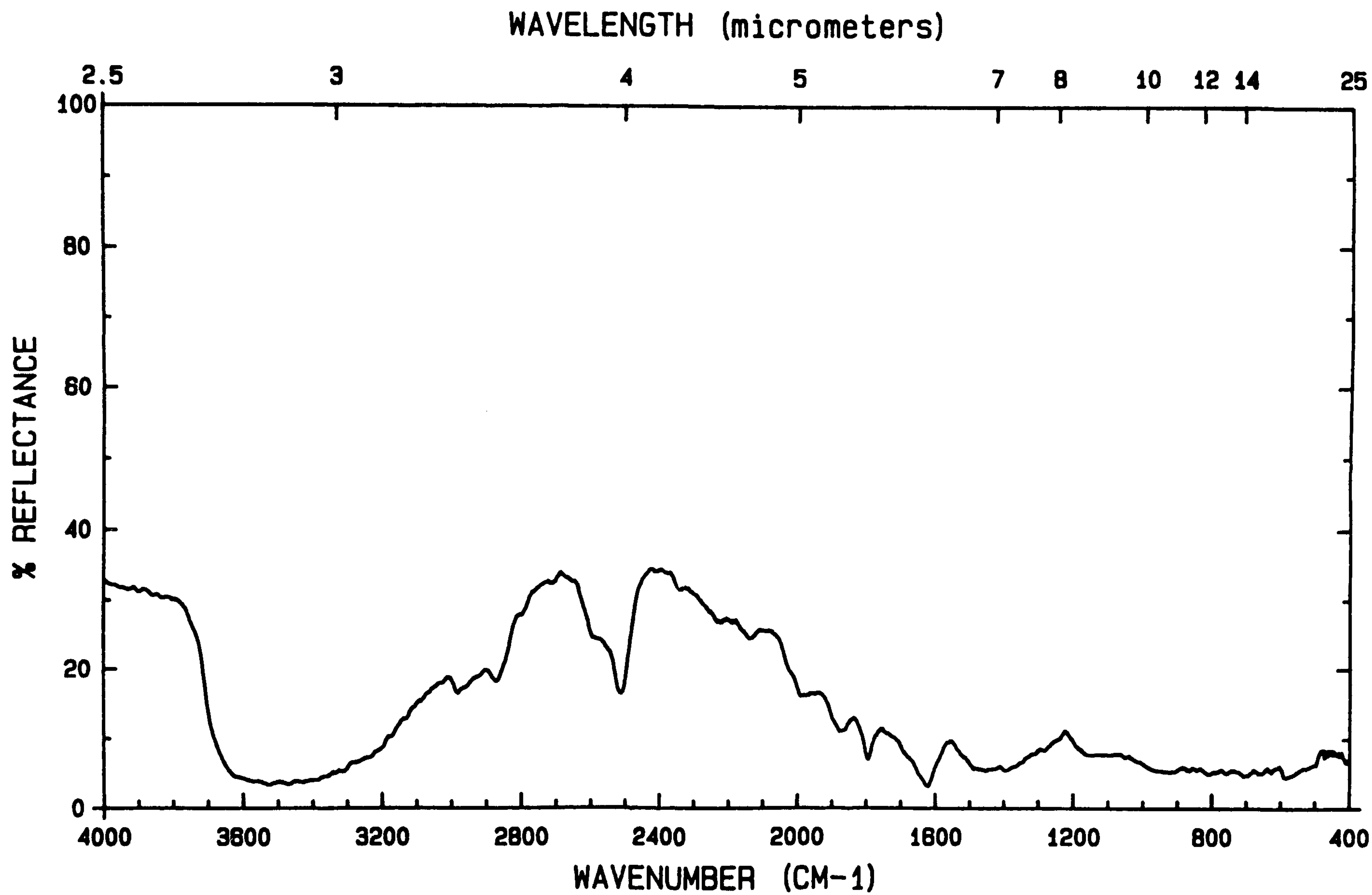
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #3

Origin: South central Egypt

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is predominantly a silicate material dominated by quartz which yields a strong reflectance maximum, due to Si-O stretching, centered at 8.6 micrometers accompanied by a weaker doublet at 12.6 micrometers. The broad water band near 2.9 micrometers and the sharper hydroxyl band near 2.7 micrometers stem from small amounts of clay and/or small inclusions of water.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #4

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

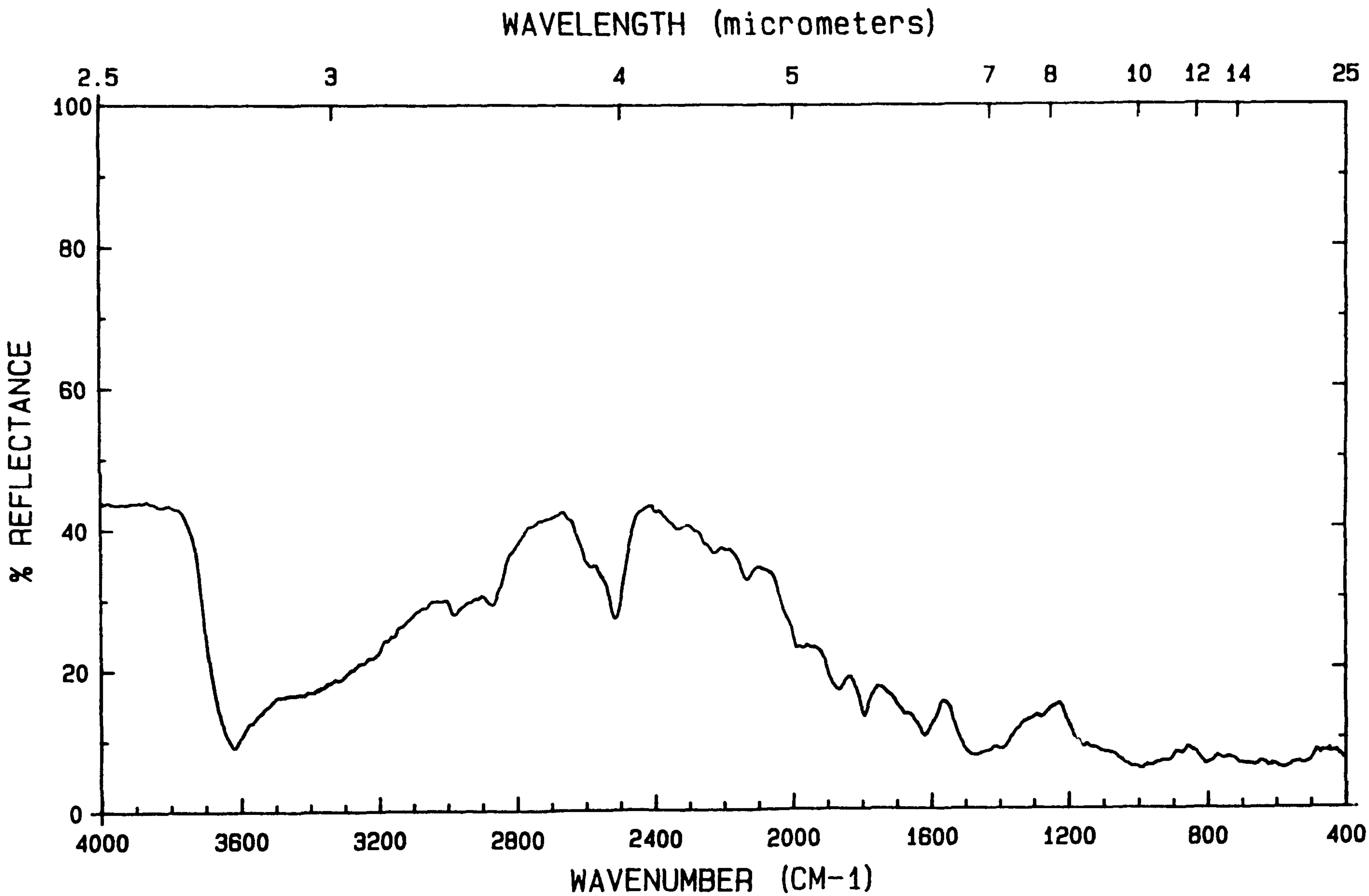
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #4

Origin: Iran, Kavir

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is composed of fine silicate material plus a condiderable amount of carbonate (limestone). The broad water band near 2.9 micrometers suggests the presence of clay minerals. Limestone is indicated by the strong carbonate absorption feature at 4 micrometers as well as by the carbonate maximnum at 6.3 micrometers.



WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #5

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

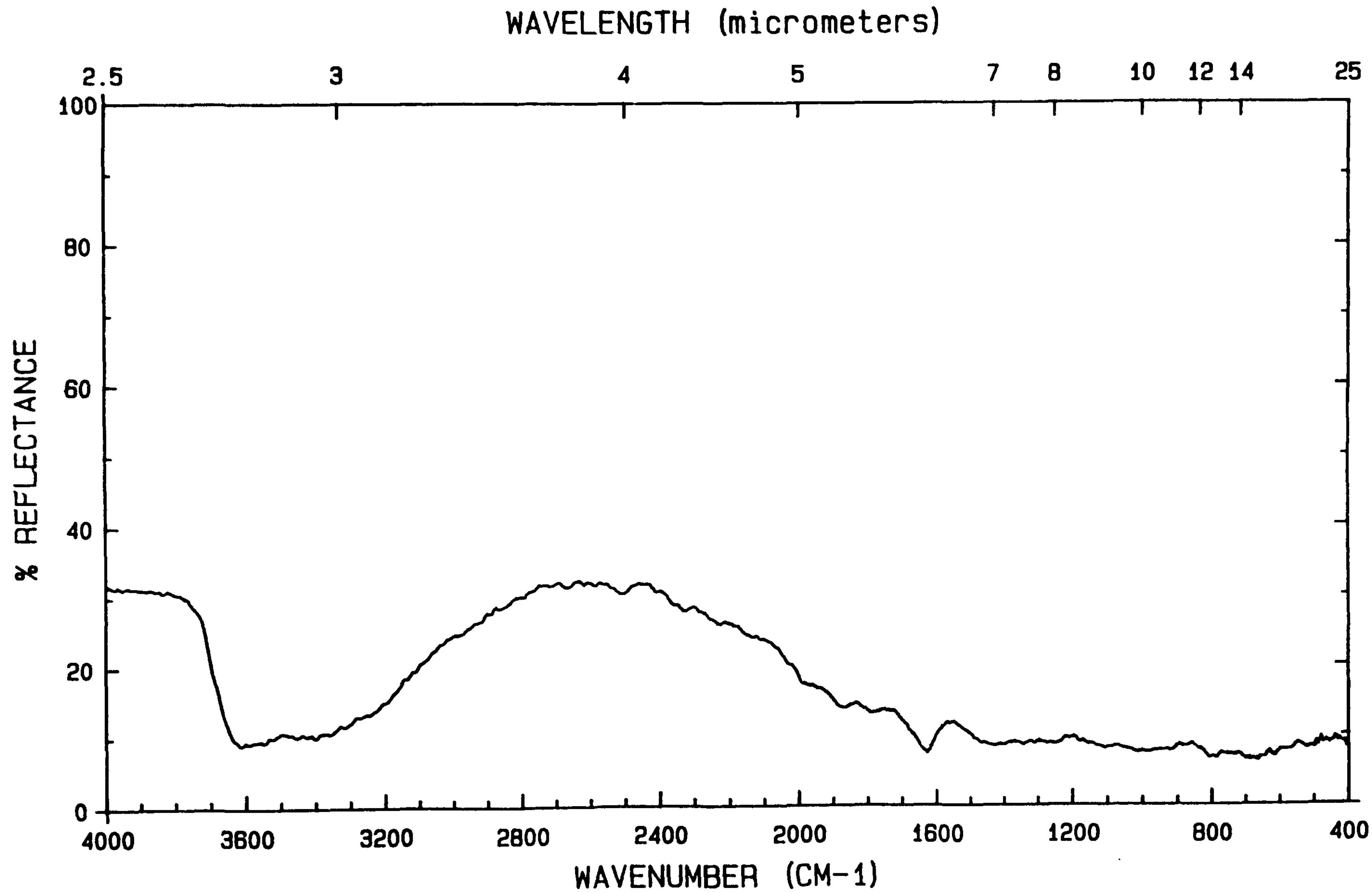
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #5

Origin: Iran, Lut

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is composed of fine silicate material plus a condiderable amount of carbonate (limestone). The broad water band near 2.9 micrometers suggests the presence of clay minerals. Limestone is indicated by the strong carbonate absorption feature at 4 micrometers as well as by the carbonate maximnum at 6.3 micrometers.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #6

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

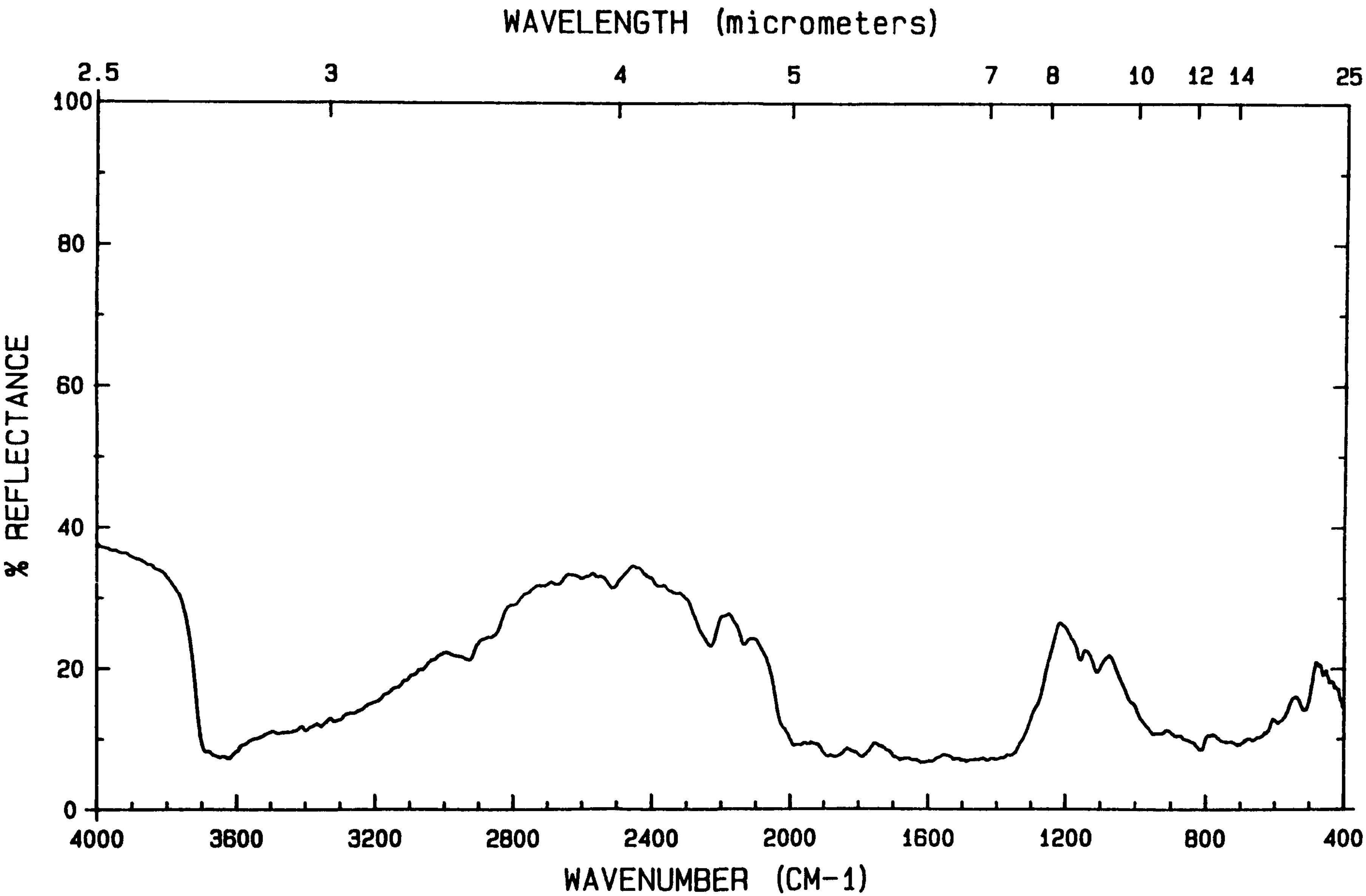
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #6

Origin: Peru, north of lower Ica valley.

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Except for water bands at 2.9 micrometers and the hydroxyl O-H stretching band at 2.7 micrometers, there is very little feature to this spectrum, which suggests fine sample particle size. Traces of carbonate are suggested by the weak feature near 6.3 micrometers together with the very shallow reflectance trough at 4 micrometers. The water and hydroxyl bands stem from small amounts of clay and/or small inclusions of water.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
% REFLECTANCE
100
80
60
40
20
0
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #7

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

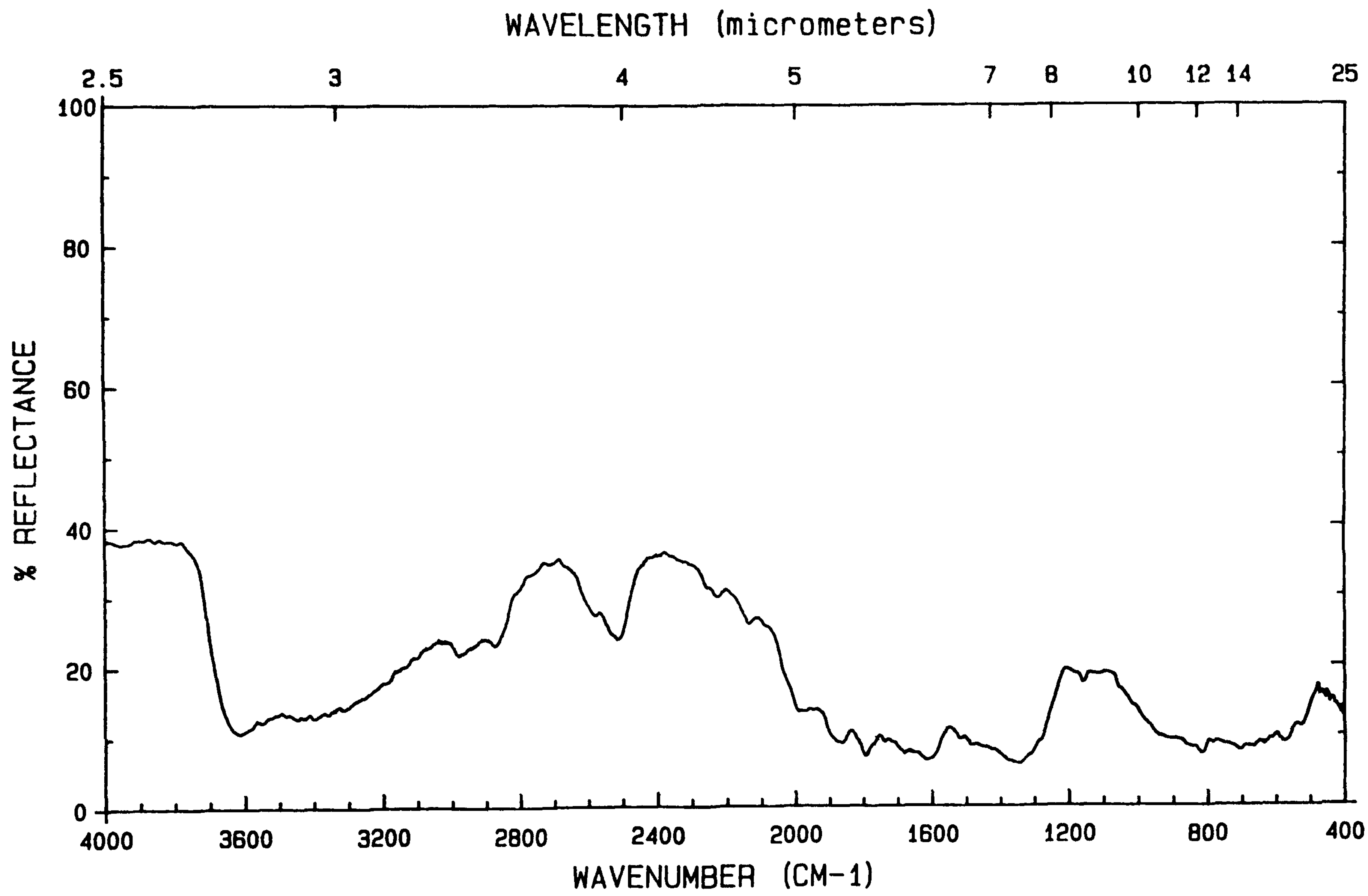
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #7

Origin: Australia, near Alice Springs

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is predominantly a silicate material dominated by quartz as evidenced by strong Si-O asymmetrical stretching vibrations near 8.6 micrometers and a weak doublet due to symmetrical Si-O stretching vibration near 12.6 micrometers. A weak maximum near 6.3 micrometers together with a small reflectance trough near 4 micrometers indicates traces of calcite. The broad water band near 2.9 micrometers and the sharp hudroxyl band at 2.7 micrometers due to O-H stretching are due to small amounts of clay in the soil. Clay coated quartz also accounts for the distortion of the quartz feature at 8.6 micrometers.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #8

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

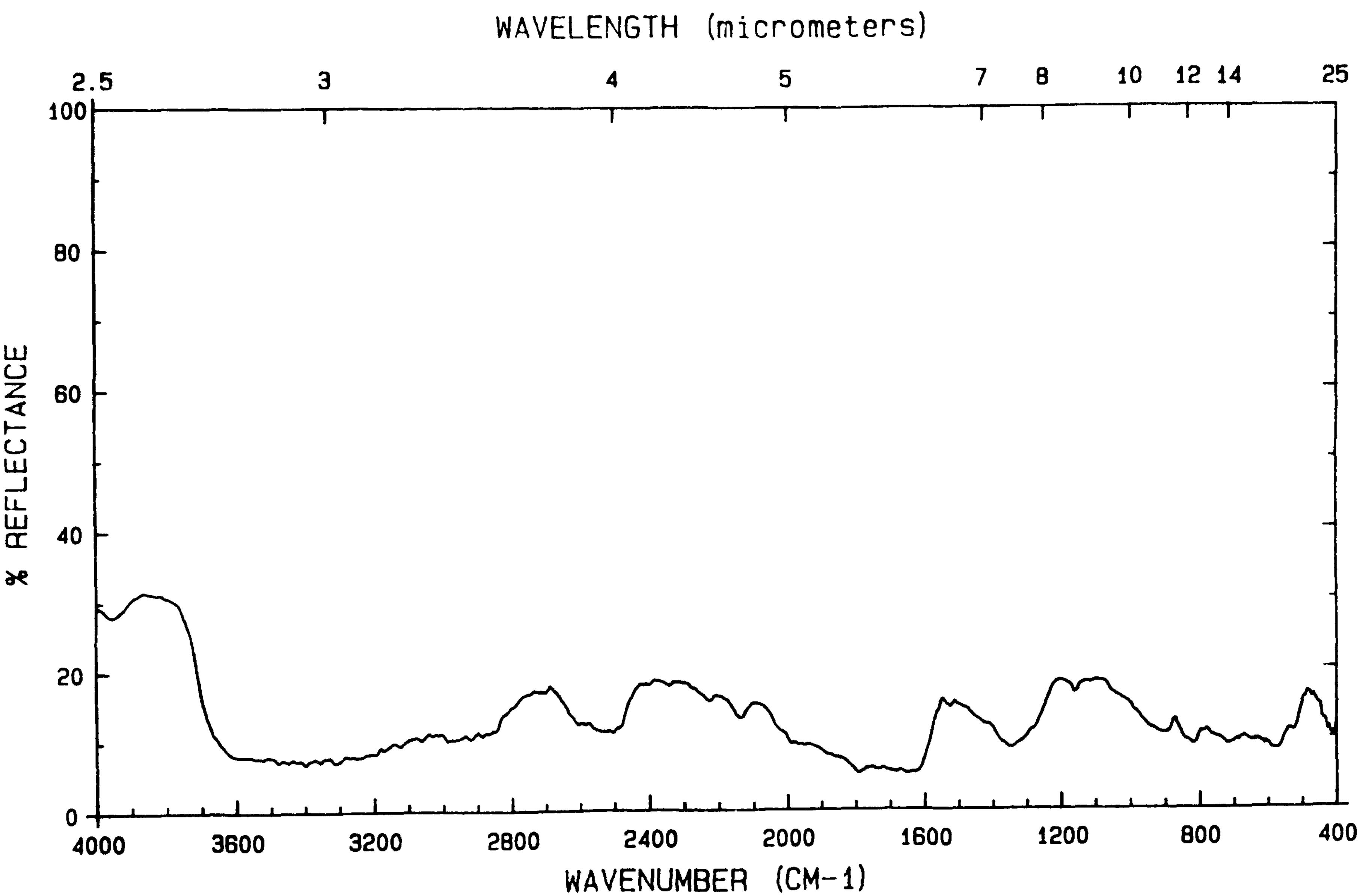
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #8

Origin: China, Chule River plain, near Hotien

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is composed of quartz and limestone. Si-O asymmetrical stretching vibrations near 8.6 micrometers and a weak doublet due to symmetrical Si-O stretching vibration near 12.6 micrometers are indicative of quartz. A weak maximum near 6.3 micrometers together with absorption at 4 micrometers indicates calcite. The broad water band near 2.9 micrometers and the sharp hudroxyl band at 2.7 micrometers due to O-H stretching are due to small amounts of clay in the soil.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #9

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

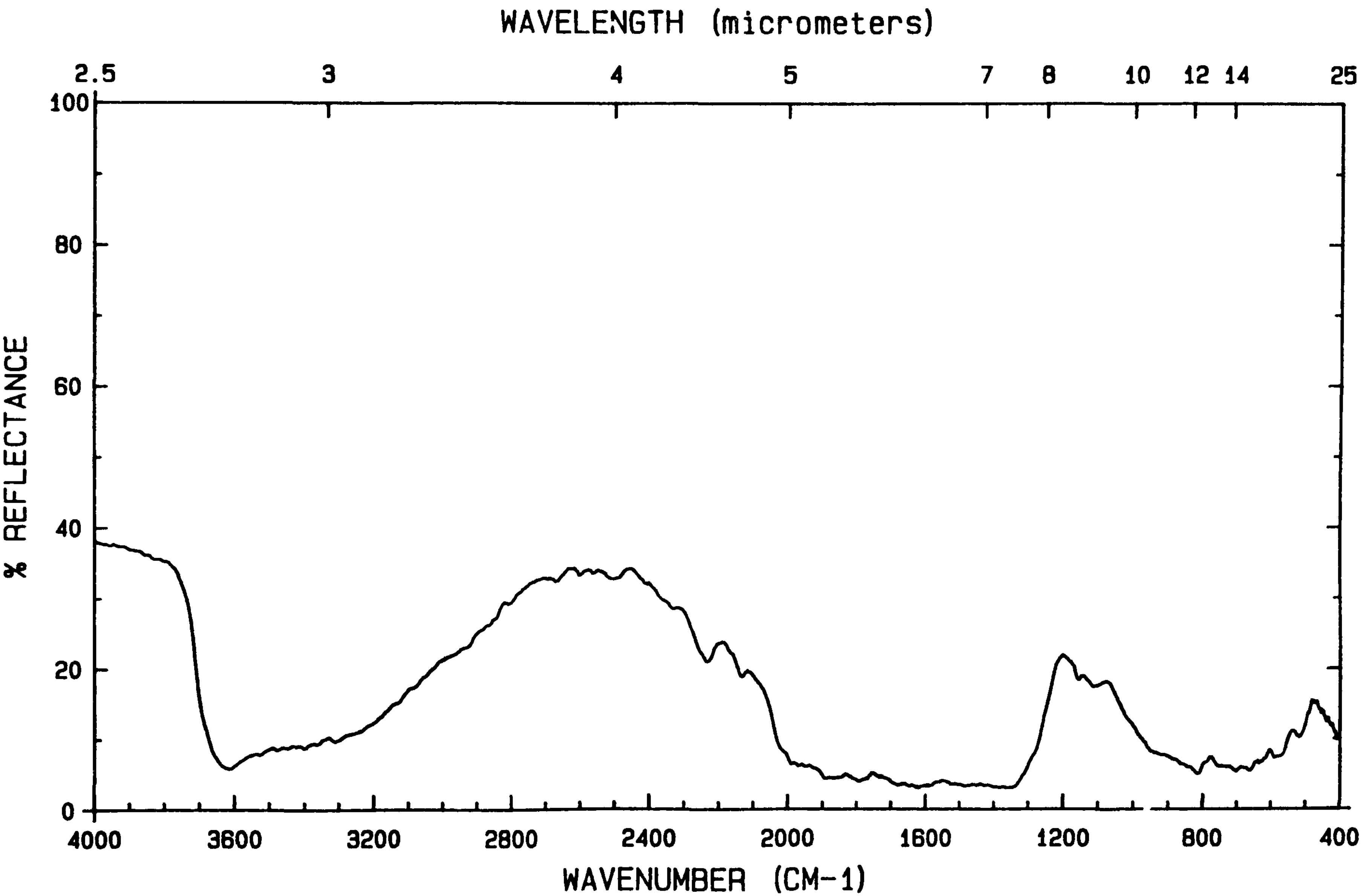
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #9

Origin: Morocco, west coast

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is composed of quartz and limestone. Si-O asymmetrical stretching vibrations near 8.6 micrometers and a weak doublet due to symmetrical Si-O stretching vibration near 12.6 micrometers are indicative of quartz. A peak near 6.3 micrometers together with absorption at 4 micrometers indicates calcite. The broad water band near 2.9 micrometers indicates small amounts of clay or water inclusions in the soil.


WAVELENGTH (micrometers)
2.5
3
4
5
7
8
10
12
14
25
100
80
60
40
20
0
% REFLECTANCE
4000
3600
3200
2800
2400
2000
1600
1200
800
400
WAVENUMBER (CM-1)

USGS SOIL #10

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

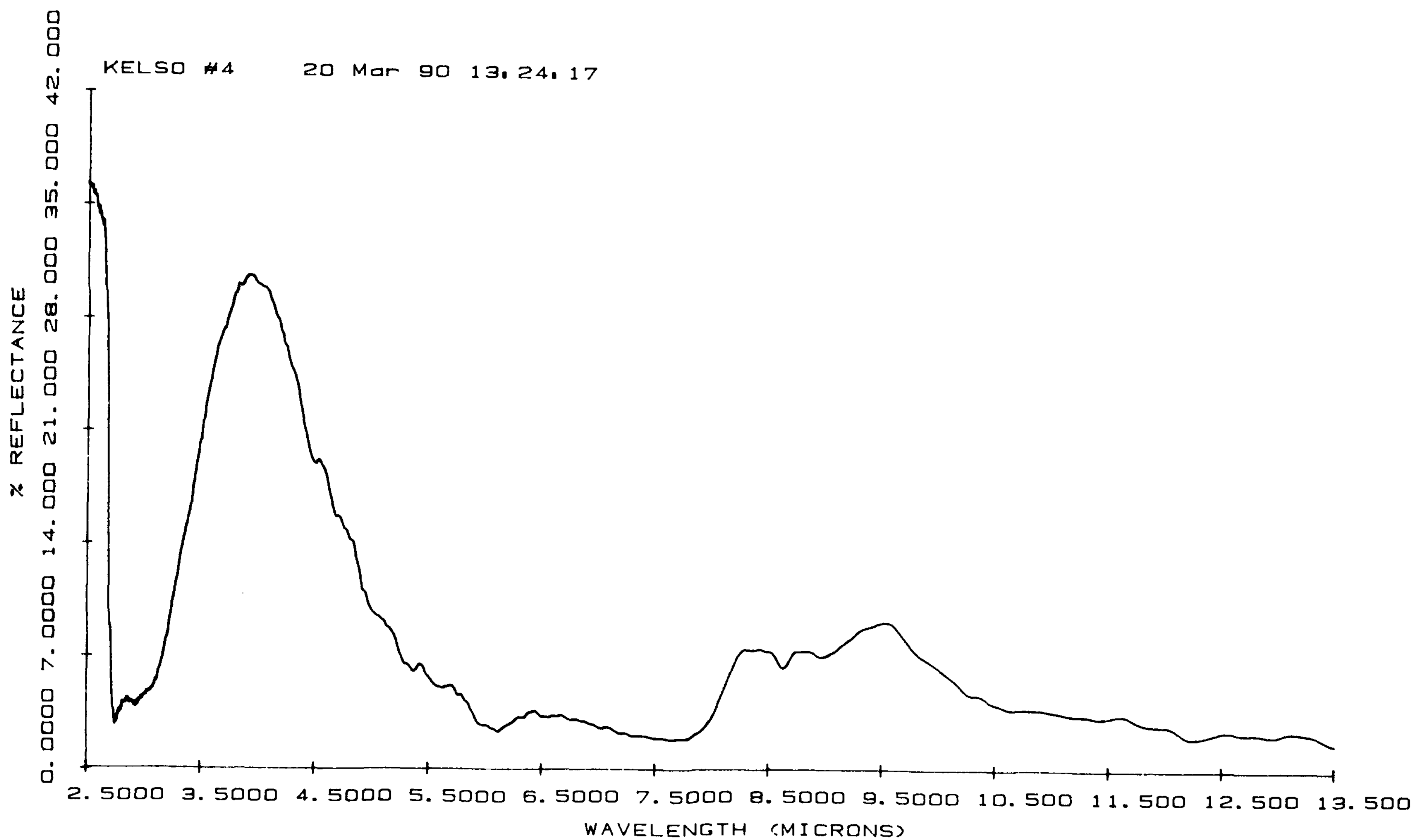
Reference: 600 grit Au coated SiC sandpaper

Sample: USGS soil #10

Origin: Yuma, AZ

Physical state: Field sample was seived; the <210 micrometer particle size fraction was used for spectral measurement.

Remarks: Spectrum indicates sample is predominantly quartz as evidenced by strong Si-O asymmetrical stretching vibrations near 8.6 micrometers and a weak doublet due to symmetrical Si-O stretching vibration near 12.6 micrometers. The broad water band near 2.9 micrometers is due to small amounts of clay or water inclusions in the soil. Clay coated quartz grains may account for the distortion of the quartz feature at 8.6 micrometers.



KELSO #4
20 Mar 90 13:24:17
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

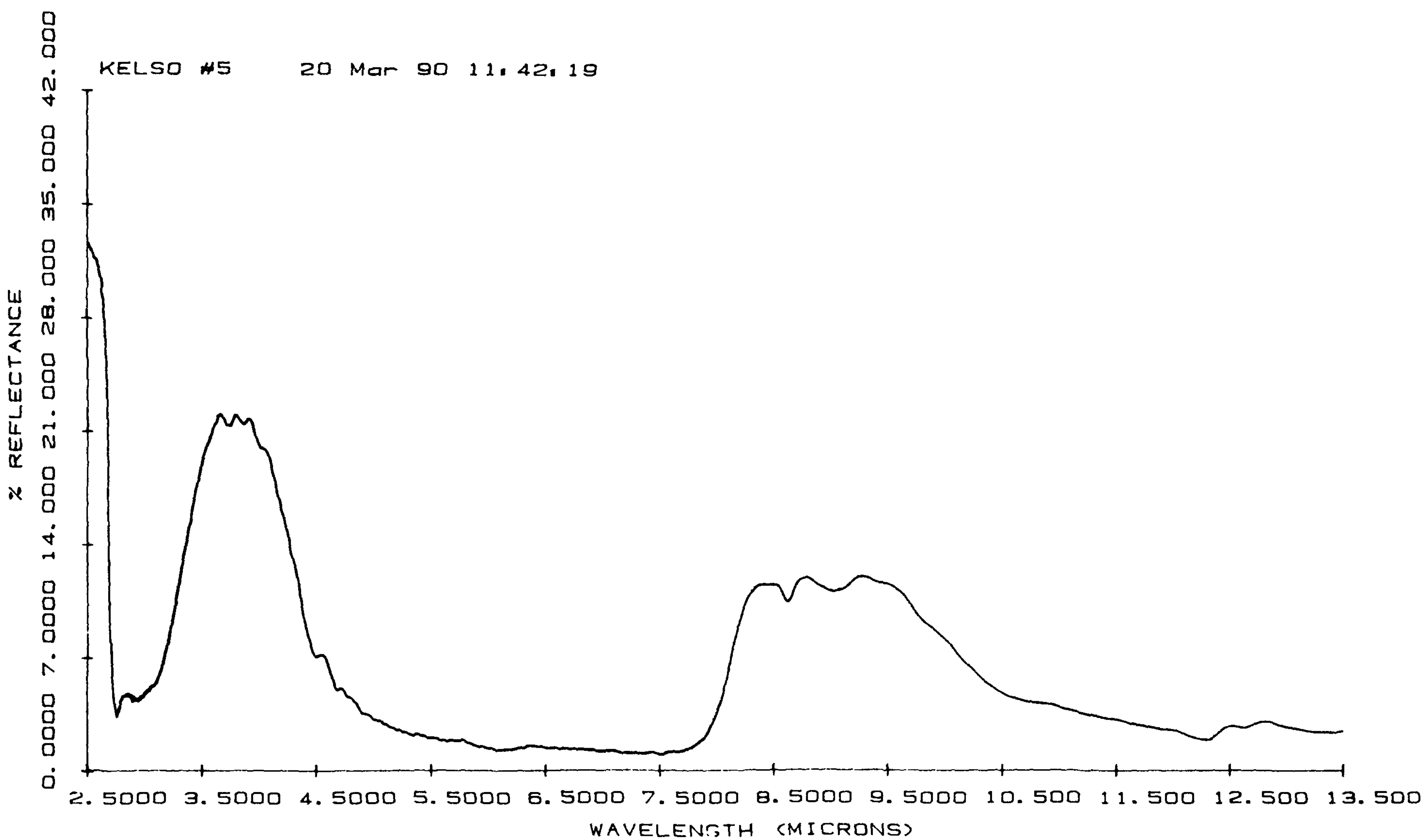
Sample: Kelso soil #4

Sample data: Sample was collected by J. W. Eastes 10 April 1987 in the Mojave Desert near the Kelso sand dune area.

Sample description: Light brown sandy soil.

Comments: Spectrum indicates sample to be a silicate rich soil with little or no carbonate component. Silicates are indicated by the fairly strong three lobed reflectance feature between about 8.0 and 10.5 micrometers. This feature is actually composed of a surface scattering reflectance doublet due to quartz plus a single clay mineral peak centered near 9.5 micrometers. The water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to the small amount of clay in the soil. Clay coatings on quartz grains acount for the reflectance maximum at 9.5 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.



KELSO #5
20 Mar 90 11:42:19
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

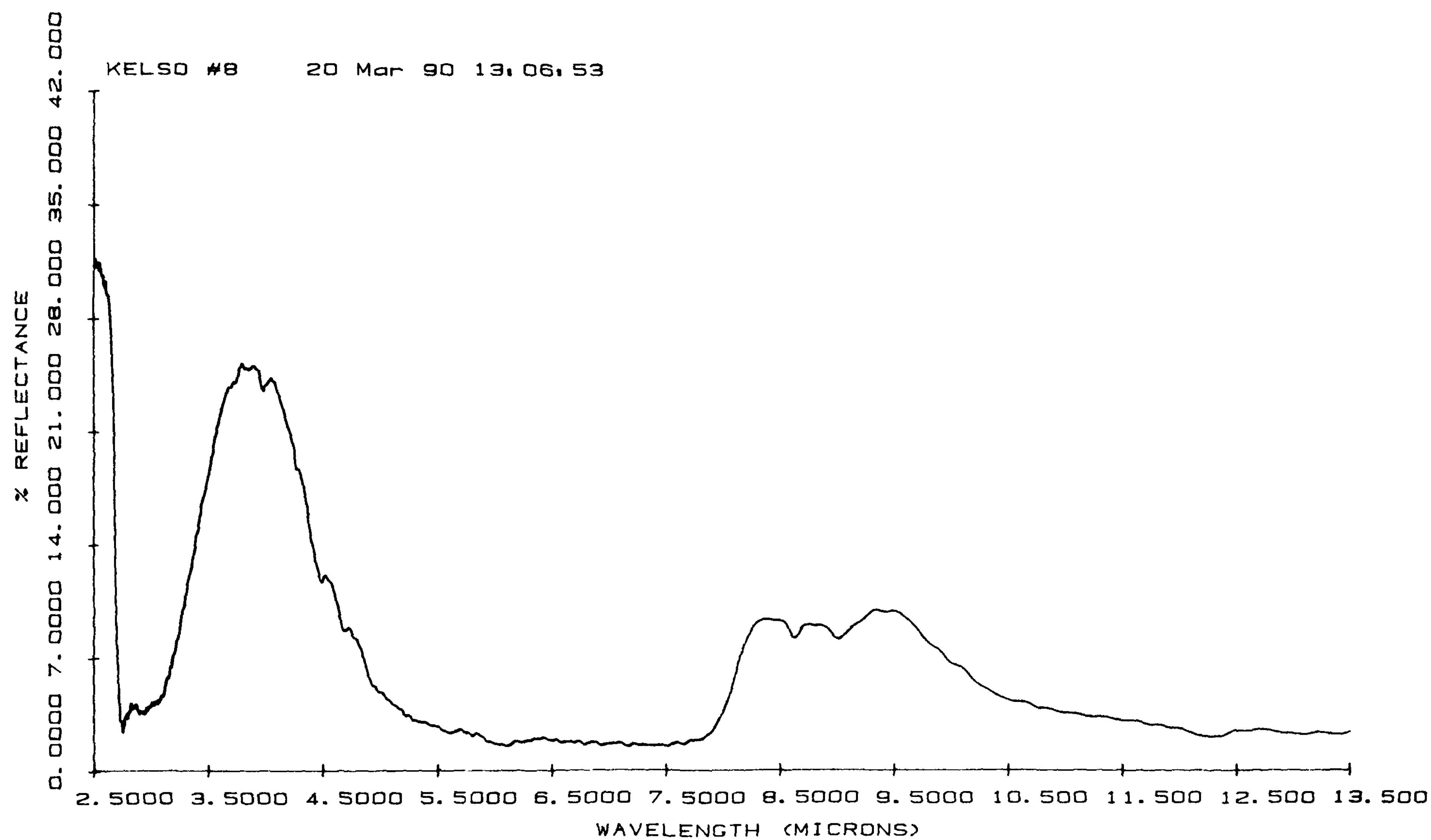
Sample: Kelso soil #5

Sample data: Sample was collected by J. W. Eastes 10 April 1987 in the Mojave Desert near the Kelso sand dune area.

Sample description: Light brown sandy soil.

Comments: Spectrum indicates sample to be a silicate rich soil with little or no carbonate component. Silicates are indicated by the fairly strong three lobed reflectance feature between about 8.0 and 10.5 micrometers. This feature is actually composed of a surface scattering reflectance doublet due to quartz plus a single clay mineral peak centered near 9.5 micrometers. A second weaker doublet, also due to quartz, appears near 12.6 micrometers. The water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to the small amount of clay in the soil. Clay coatings on quartz grains acount for the reflectance maximum at 9.5 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.


KELSO #8 20 Mar 90 13:06:53
% REFLECTANCE
0.0000 7.0000 14.000 21.000 28.000 35.000 42.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

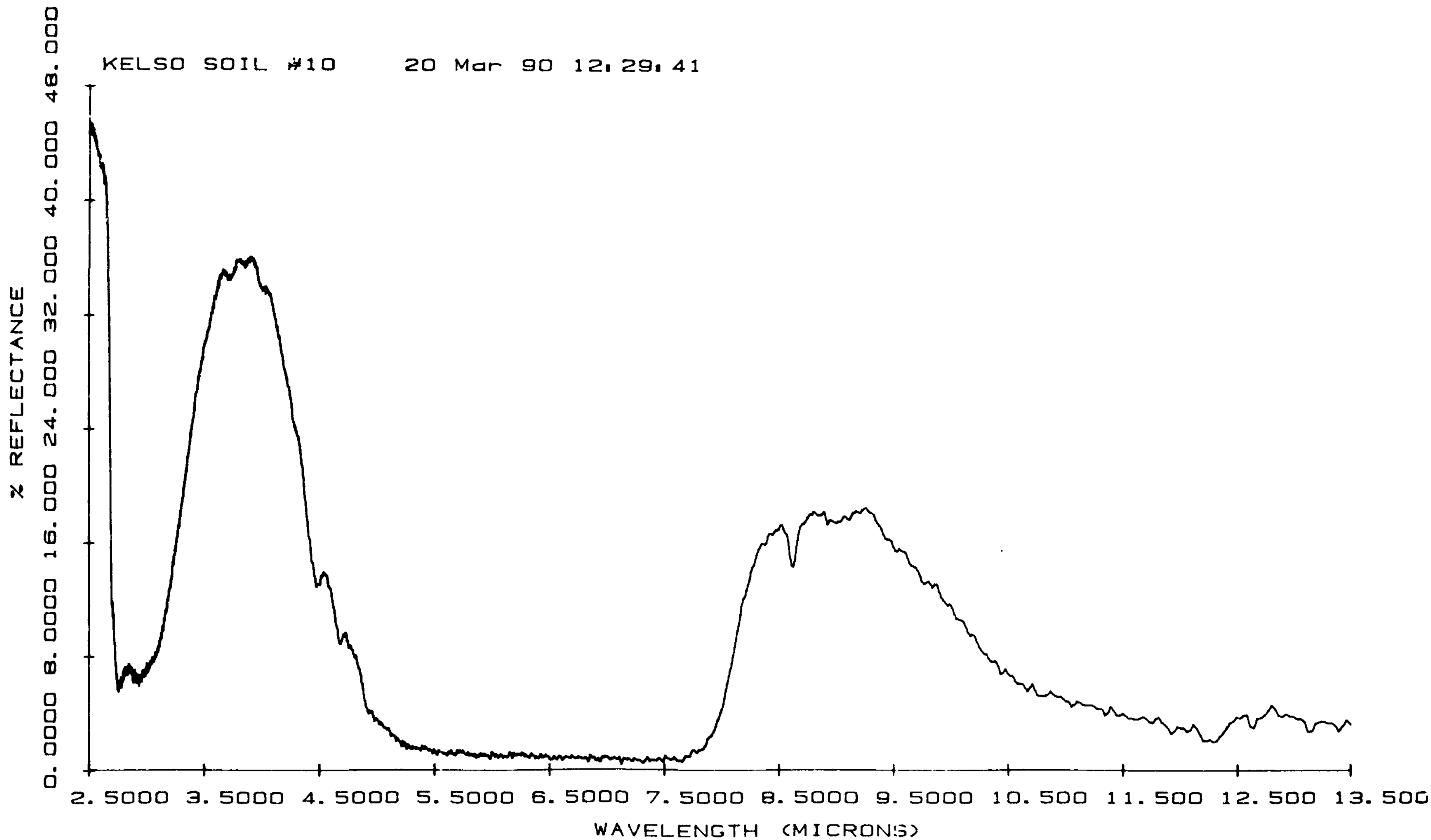
Sample: Kelso soil #8

Sample data: Sample was collected by J. W. Eastes 10 April 1987 in the Mojave Desert near the Kelso sand dune area.

Sample description: Light brown sandy soil.

Comments: Spectrum indicates sample to be a silicate rich soil with little or no carbonate component. Silicates are indicated by the fairly strong three lobed reflectance feature between about 8.0 and 10.5 micrometers. This feature is actually composed of a surface scattering reflectance doublet due to quartz plus a single clay mineral peak centered near 9.5 micrometers. A second very faint doublet, also due to quartz, appears near 12.6 micrometers. The water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to the small amount of clay in the soil. Clay coatings on quartz grains acount for the reflectance maximum at 9.5 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.



KELSO SOIL #10
20 Mar 90 12:29:41
% REFLECTANCE
0.0000
8.0000
16.000
24.000
32.000
40.000
48.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

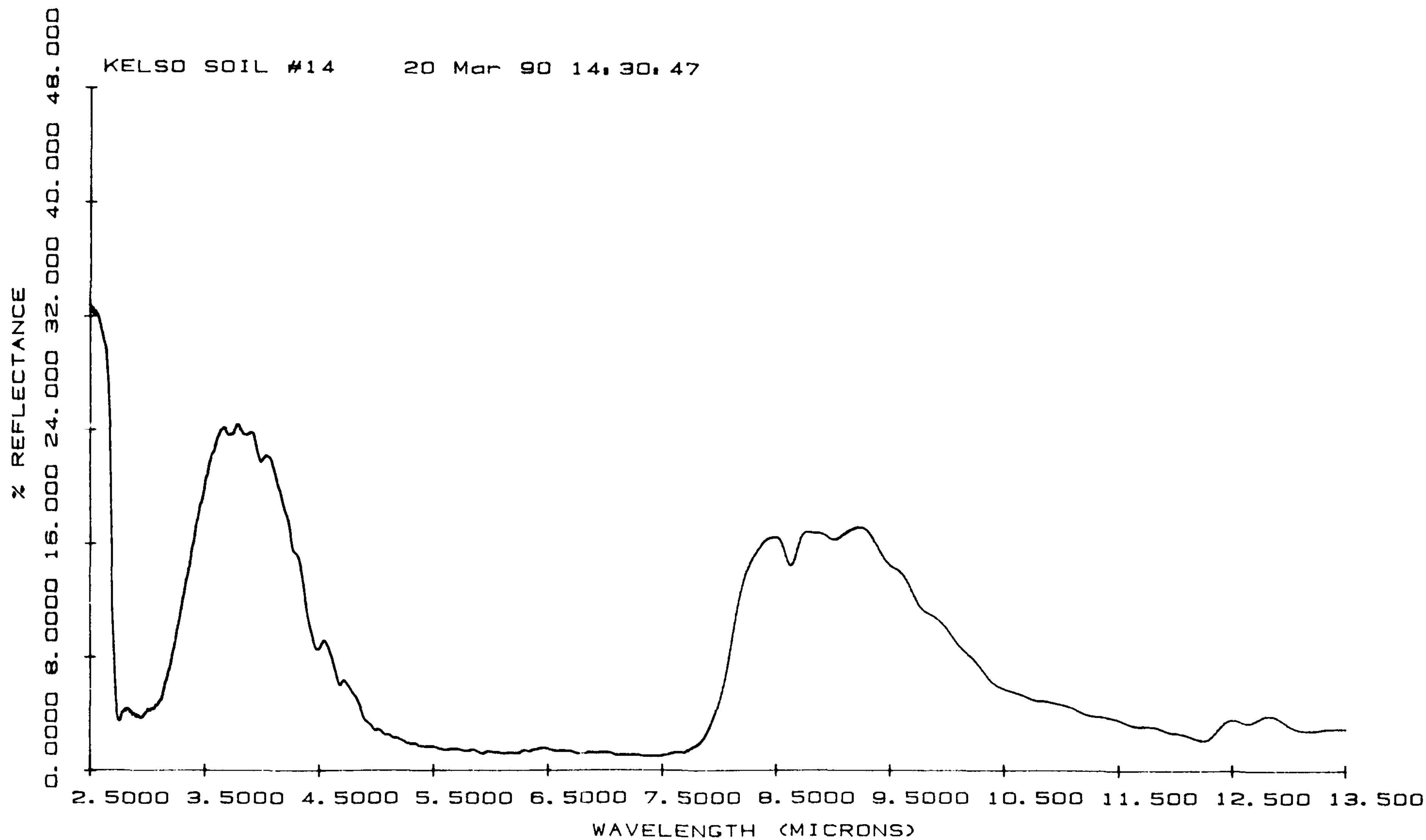
Sample: Kelso soil #10

Sample data: Sample was collected by J. W. Eastes 10 April 1987 in the Mojave Desert near the Kelso sand dune area.

Sample description: Dune sand

Comments: Spectrum indicates sample to consist mainly of quartz. Clay coated quartz grains are indicated by the strong three lobed reflectance feature between 8 and 10.5 micrometers. This feature is actually composed of a surface scattering reflectance doublet due to quartz plus a clay mineral peak centered near 9.5 micrometers. A second weaker doublet, also due to quartz, appears near 12.6 micrometers. The water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to the small amount of clay in the soil.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.



KELSO SOIL #14 20 Mar 90 14:30:47
% REFLECTANCE
0.0000 8.0000 16.000 24.000 32.000 40.000 48.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

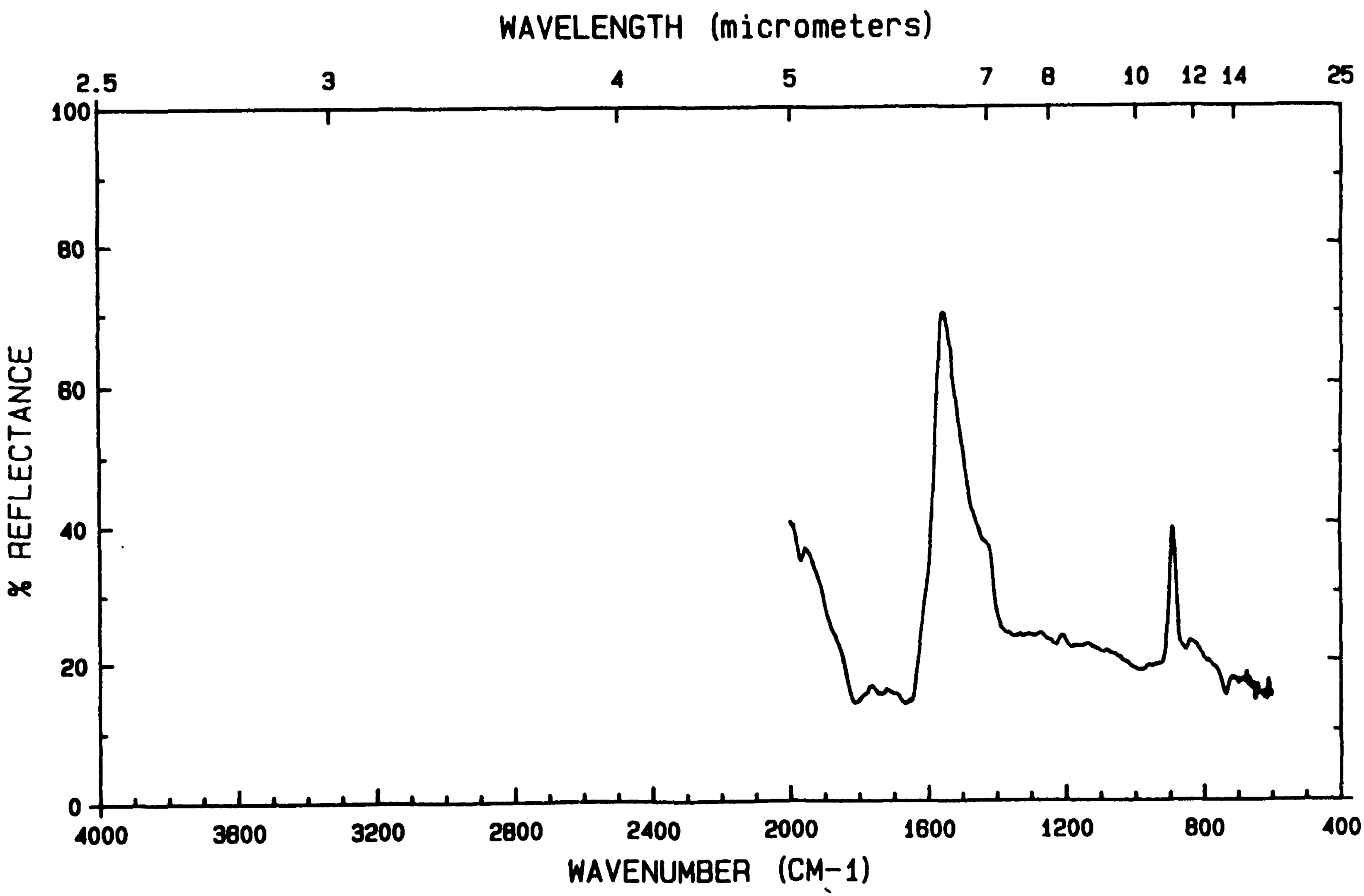
Sample: Kelso soil #14

Sample data: Sample was collected by J. W. Eastes 10 April 1987 in the Mojave Desert near the Kelso sand dune area.

Sample description: Light brown sandy soil.

Comments: Spectrum indicates sample to be a silicate rich soil with little or no carbonate component. Silicates are indicated by the strong three lobed reflectance feature between about 8.0 and 10.5 micrometers. This feature is actually composed of a surface scattering reflectance doublet due to quartz plus a single clay mineral peak centered near 9.5 micrometers. A second very faint doublet, also due to quartz, appears near 12.6 micrometers. The water band at 2.9 micrometers and sharper hydroxyl band at 2.7 micrometers due to O-H stretching vibrations are due to the small amount of clay in the soil. Clay coatings on quartz grains acount for the reflectance maximum at 9.5 micrometers.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.



CARBONATE ROCK

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

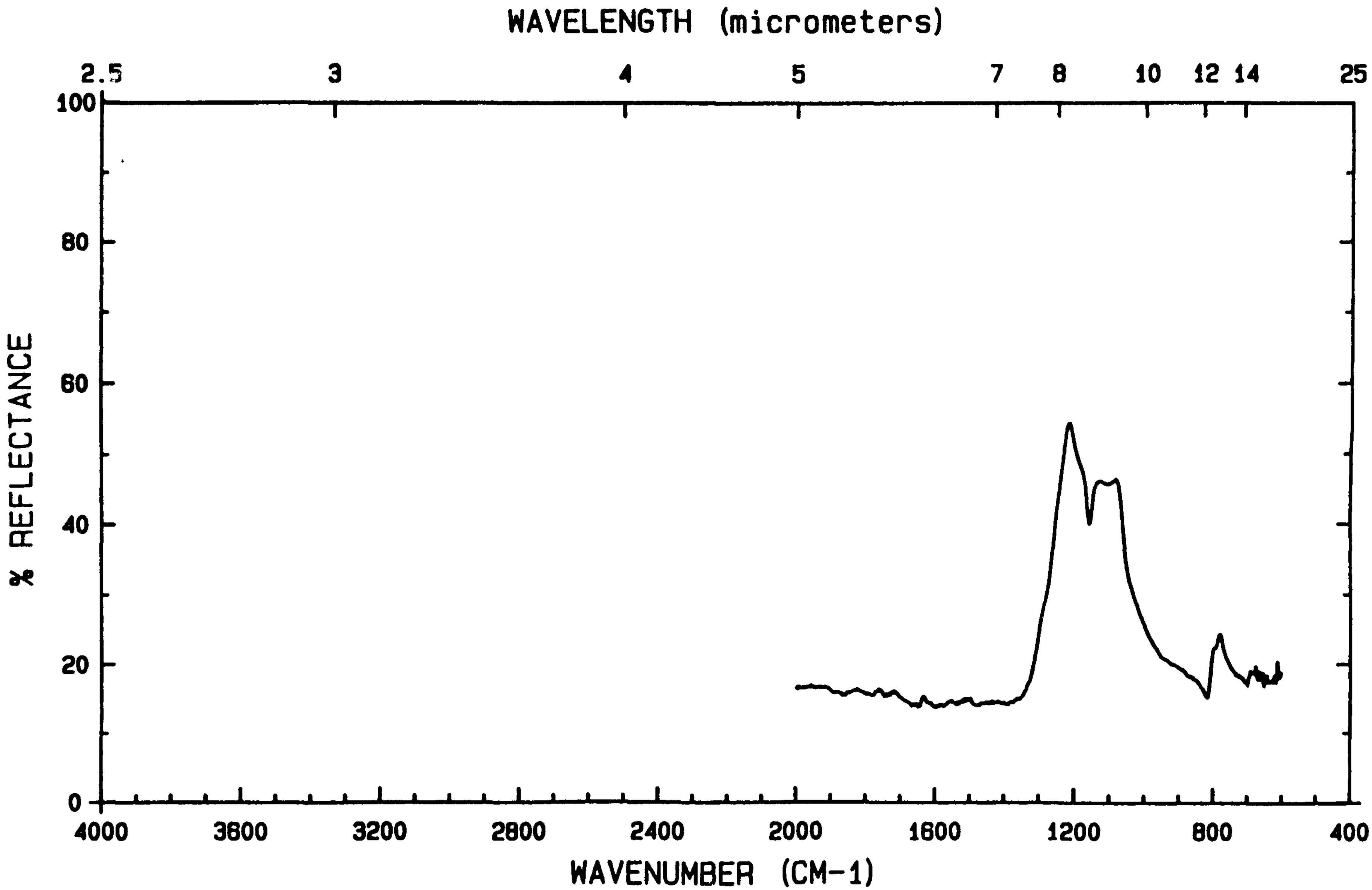
Reference: Particulate KBr <75 micrometers)

Sample: Carbonate rock

Origin: Death Valley, CA

Physical state: Small solid hand sample

Remarks: Sample was collected in April 1985 by J.W. Eastes in the Trail Canyon area of Death Valley. Spectrum is essentially that of solid calcite. particulate minerals dispersed in NaCl. The study attempts to model spectral properties of highly saline environments encountered in desert basins such as Death Valley, CA.



UNVARNISHED QUARTZITE

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

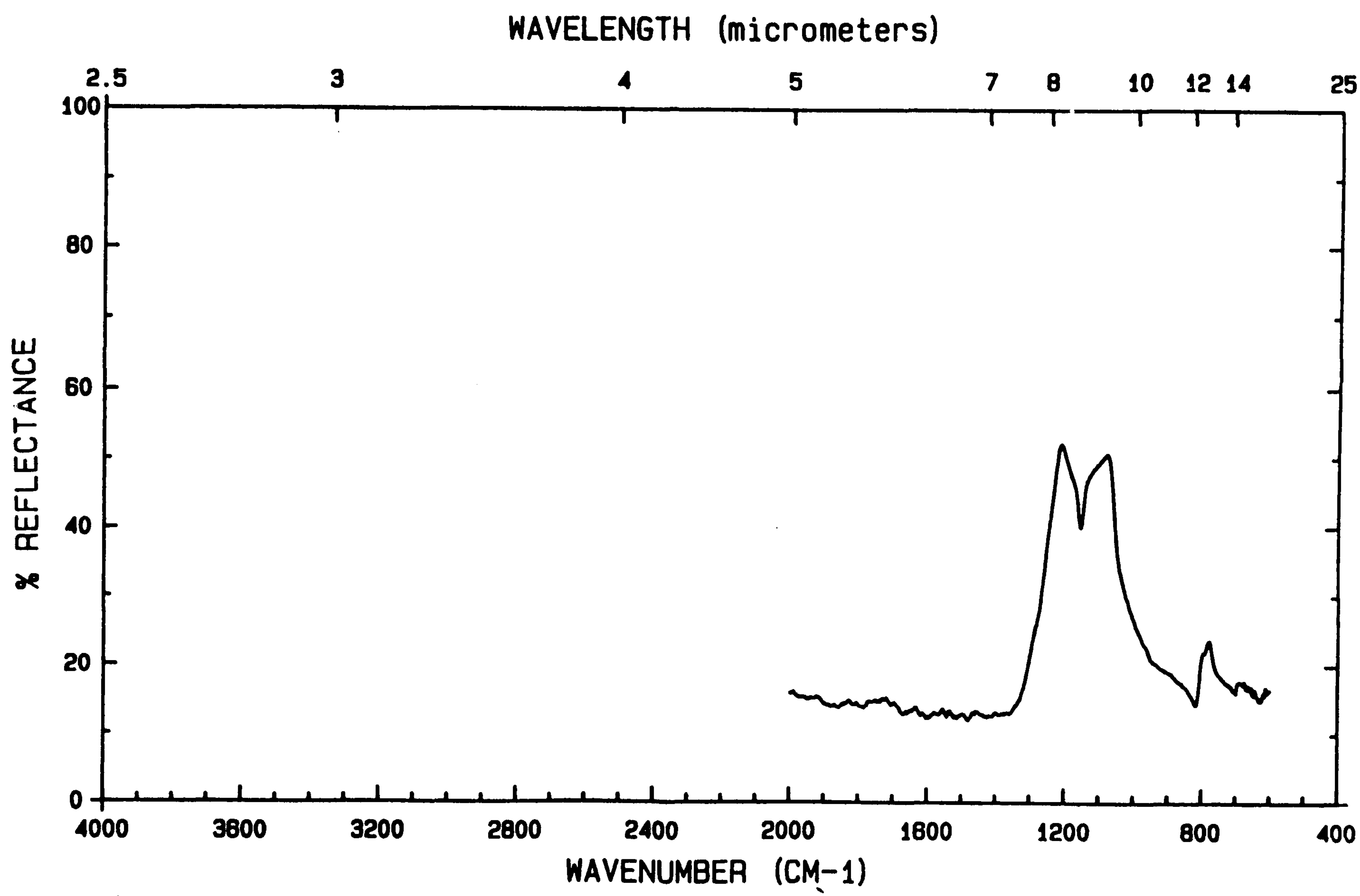
Reference: Particulate KBr <75 micrometers)

Sample: Unvarnished quartzite

Origin: Death Valley, CA

Physical state: Small solid hand sample

Remarks: Sample was collected in April 1985 by J.W. Eastes in the Trail Canyon area of Death Valley. Spectrum is essentially that of solid quartz which yields a strong surface scattering doublet centered near 8.6 micrometers due to asymmetric Si-O stretching vibrations, accompanied by the weaker doublet at 12.6 micrometers typical of alpha quartz. The longer wavelength lobe of the doublet at 8.6 micrometers is somewhat distorted. The sample was judged by eye to be unvarnished; the distortion may be due to weathering.



LIGHTLY VARNISHED QUARTZITE

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

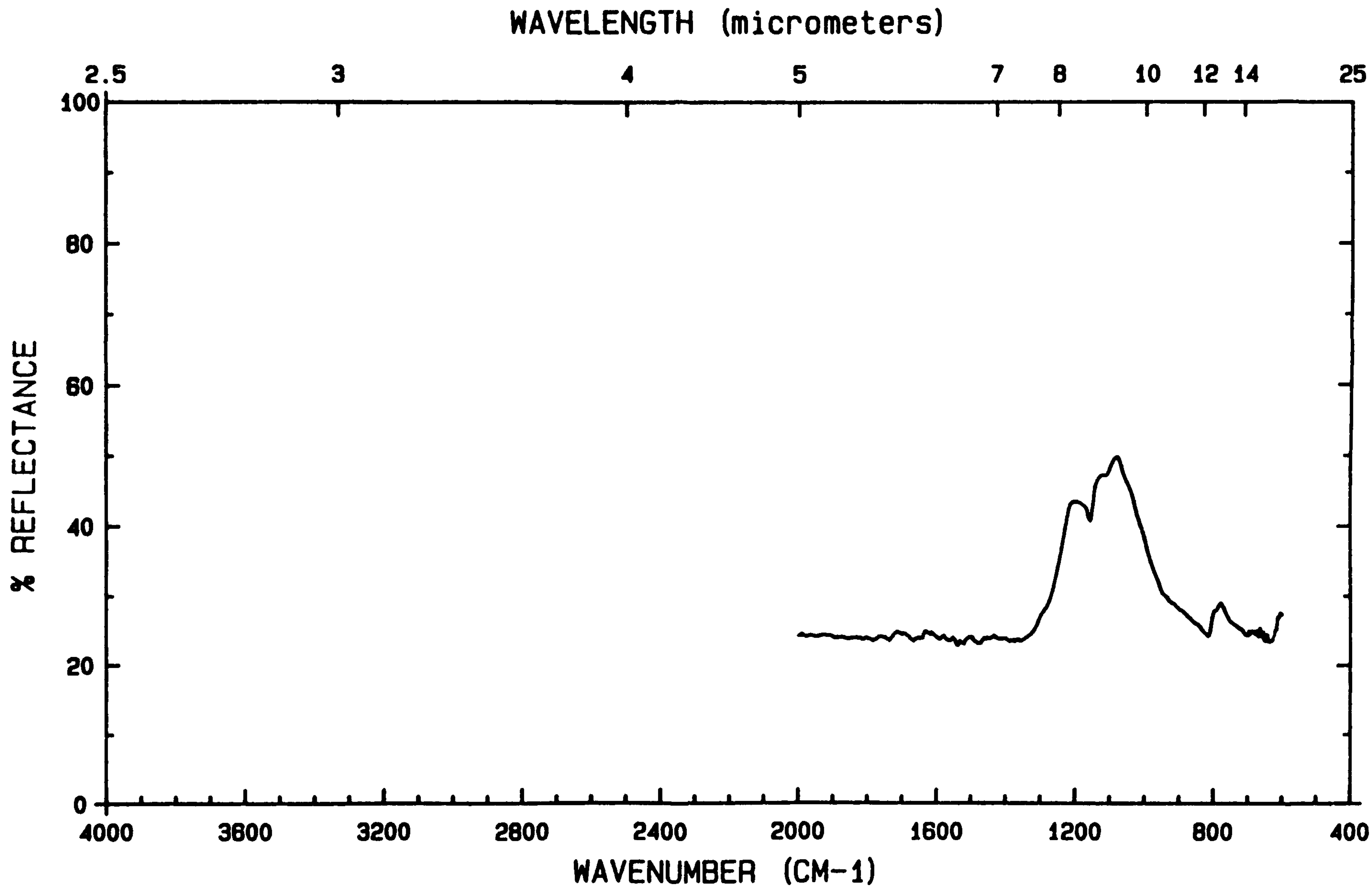
Reference: Particulate KBr <75 micrometers)

Sample: Lightly varnished quartzite

Origin: Death Valley, CA

Physical state: Small solid hand sample

Remarks: Sample was collected in April 1985 by J.W. Eastes in the Trail Canyon area of Death Valley. Spectrum is essentially that of solid quartz which yields a strong surface scattering doublet centered near 8.6 micrometers due to asymmetric Si-O stretching vibrations, accompanied by the weaker doublet at 12.6 micrometers typical of alpha quartz. The sample appeared lightly varnished to the eye, however the varnish coat is apparently too thin to signifiicantly affect spectral features.



VARNISHED QUARTZITE

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

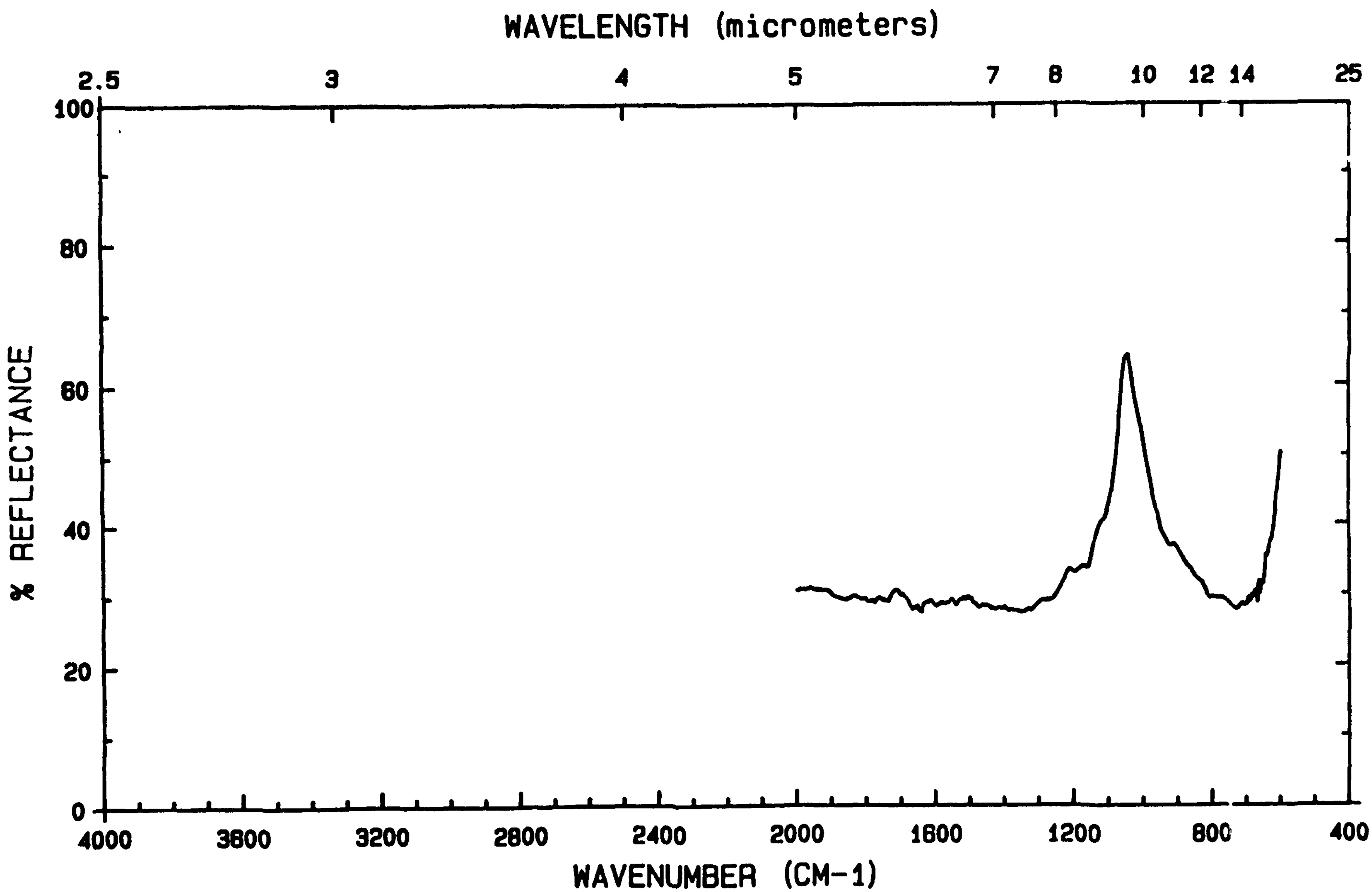
Reference: Particulate KBr <75 micrometers)

Sample: Varnished quartzite

Origin: Death Valley, CA

Physical state: Small solid hand sample

Remarks: Sample was collected in April 1985 by J.W. Eastes in the Trail Canyon area of Death Valley. Spectrum is essentially that of solid quartz which yields a strong surface scattering doublet centered near 8.6 micrometers due to asymmetric Si-O stretching vibrations, accompanied by the weaker doublet at 12.6 micrometers typical of alpha quartz. The longer wavelength lobe of the 8.6 micrometer doublet is distorted by desert varnish. Desert varnish exhibits a reflectance peak near 9.4 micrometers due to the presence of clay minerals in its composition.



HEAVILY VARNISHED QUARTZITE

SPECTRAL DATA

Acquisition of spectrum: Spectrum was acquired with a Perkin-Elmer Model 983 spectrophotometer having the following resolution:

Spectral Range	Resolution
4000-3000 cm(-1)	24 cm(-1)
3000-1800 cm(-1)	12 cm(-1)
1800-600 cm(-1)	8 cm(-1)
600-400 cm(-1)	18 cm(-1)

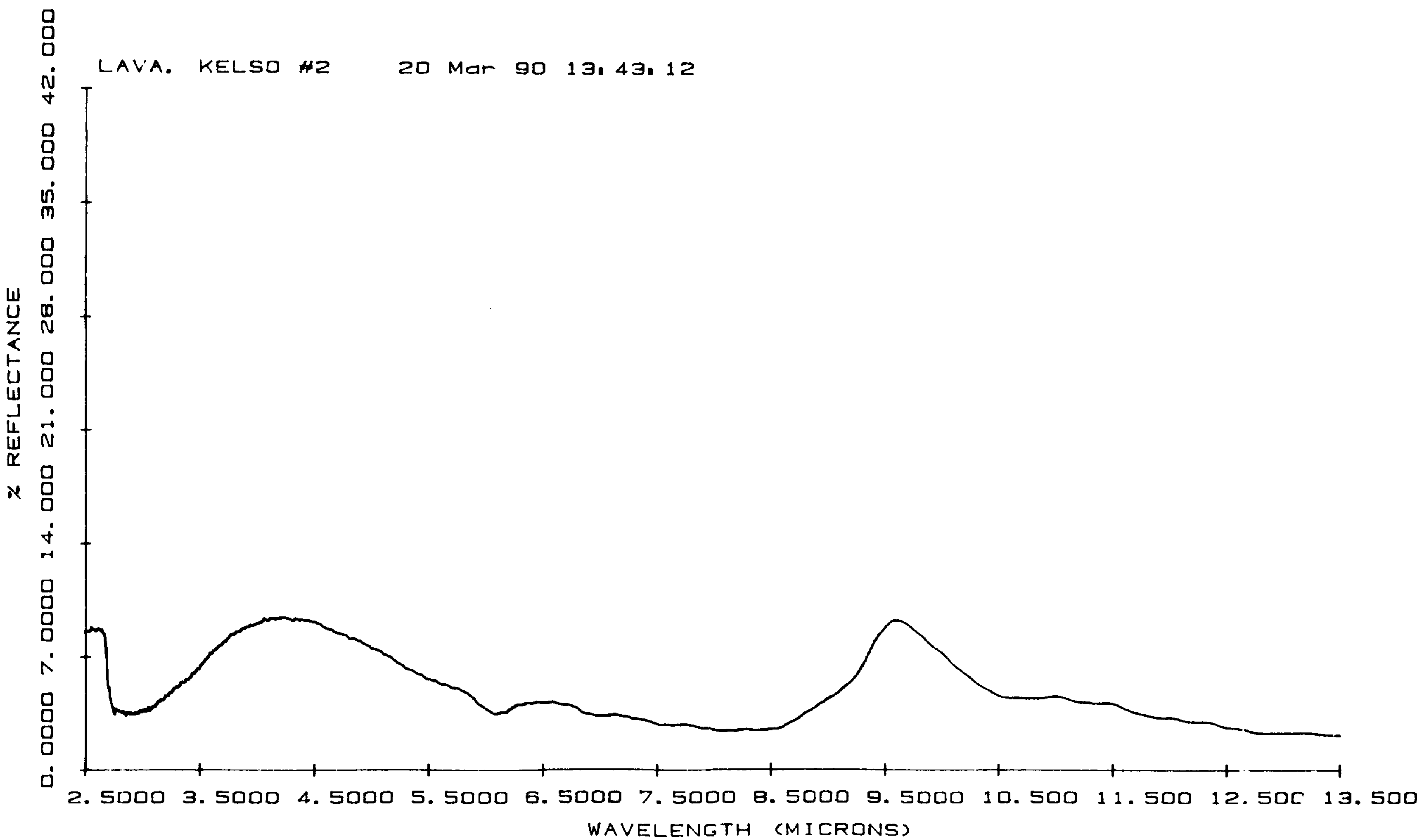
Reference: Particulate KBr <75 micrometers)

Sample: Heavily varnished quartzite

Origin: Death Valley, CA

Physical state: Small solid hand sample

Remarks: Sample was collected in April 1985 by J.W. Eastes in the Trail Canyon area of Death Valley. Spectrum is essentially that of a clay mineral and displays surface scattering centered near 9.4 micrometers. This spectrum is an example of the spectral characteristics of a surficial coating essentially replacing those of an underlying substrate.

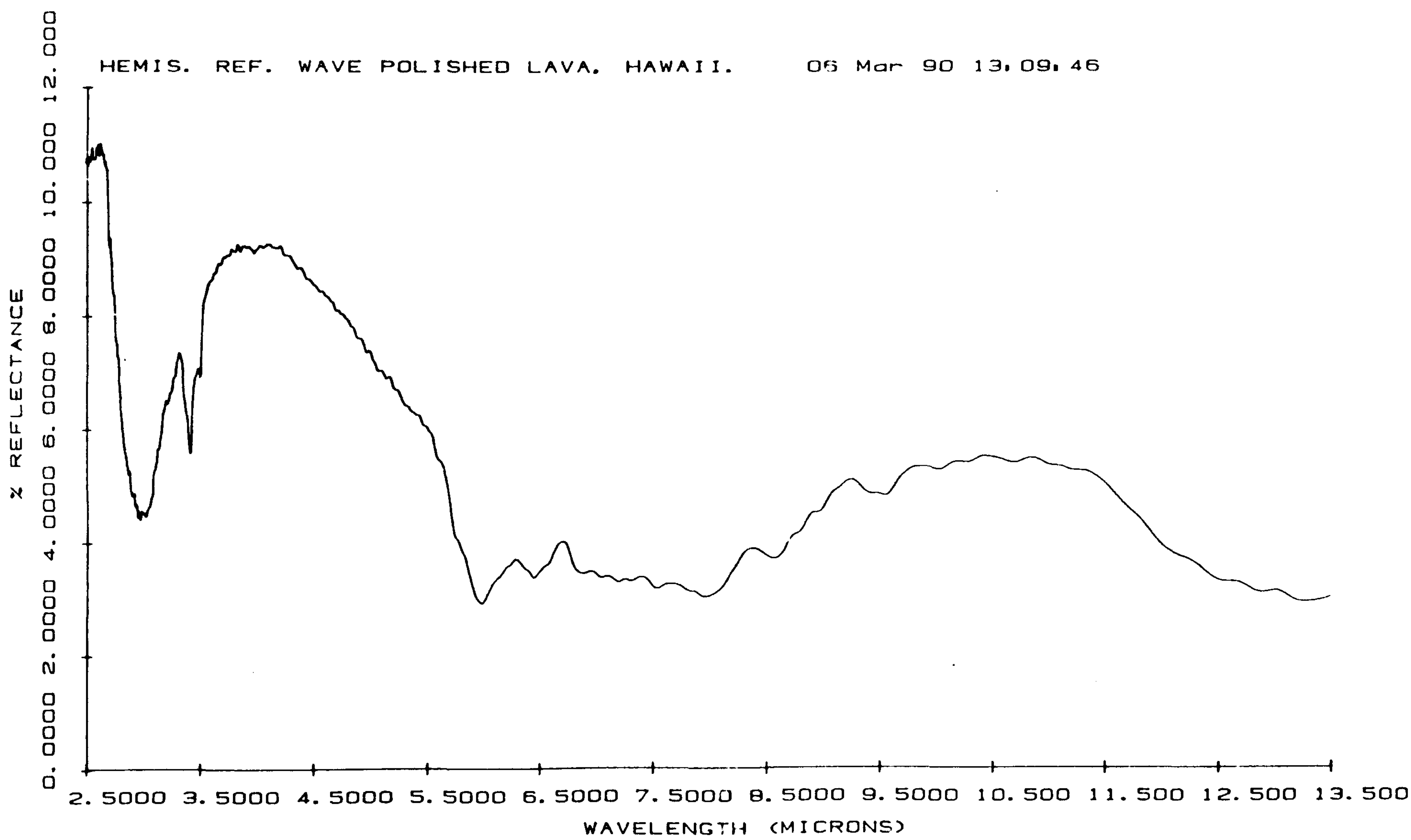


LAVA. KELSO #2
20 Mar 90 13:43:12
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.50C
13.500
WAVELENGTH (MICRONS)

Sample: Lava, Kelso #2

Sample data: Sample was collected from Cima lava field, near Kelso, California in April, 1989 by J. W. Eastes.

Comments: Sample surface is a weathered, porous basalt which has developed a thin coating of clay minerals; as a result the spectrum is dominated by clay mineral features. These include a broad water band at 2.9 micrometers and a sharper hydroxyl band at 2.7 micrometers. The sharp relatively intense band at 9.6 micrometers is also due to clay minerals.

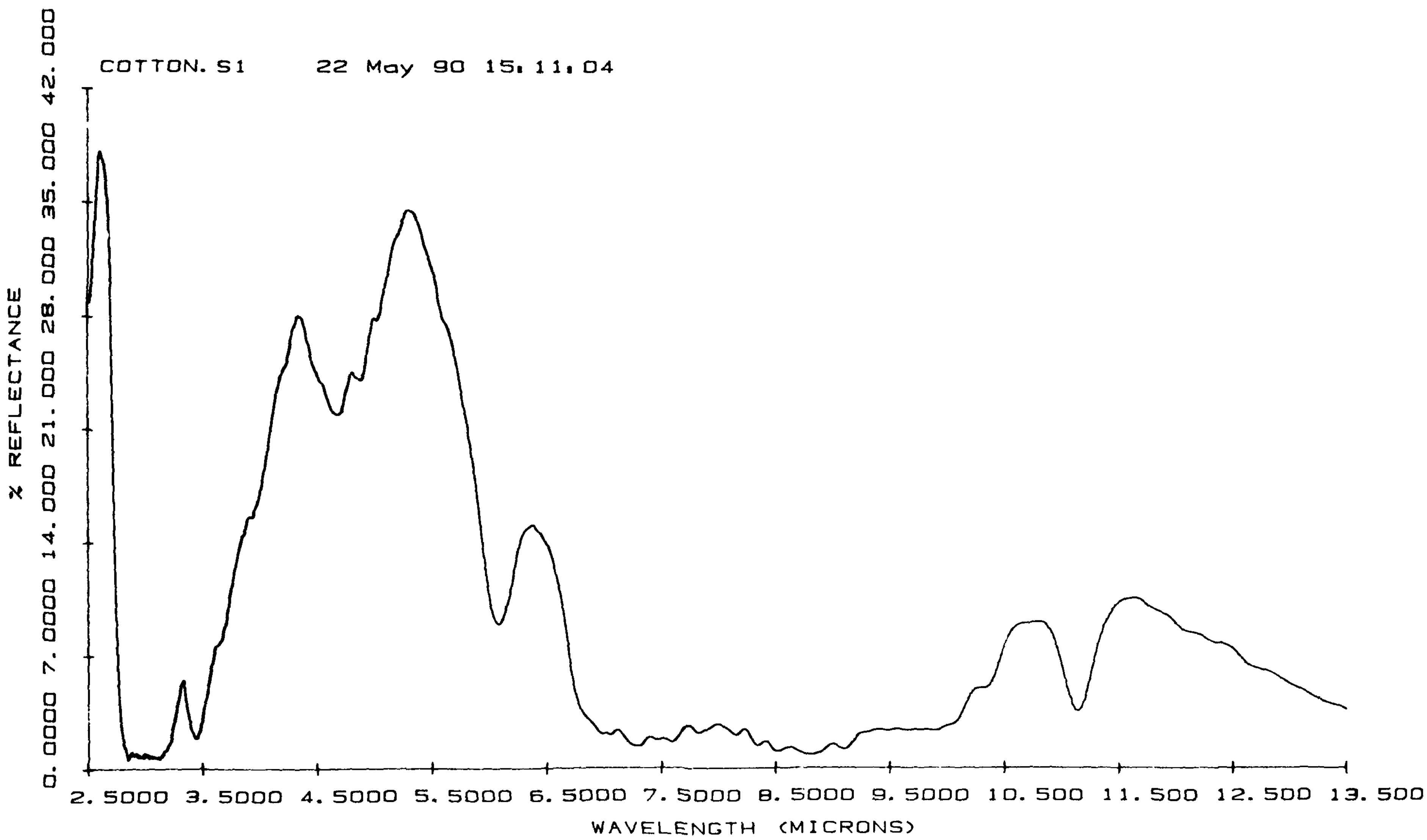

HEMIS. REF. WAVE POLISHED LAVA. HAWAII. 06 Mar 90 13:09:46
% REFLECTANCE
0.0000
2.0000
4.0000
6.0000
8.0000
10.000
12.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Hawaiian lava

Sample data: This sample of wave posilshed lava was collected 1 Mar 1975 by J. W. Eastes from a beach near Hilo, Hawaii.

Comments: Spectrum is essentially that of weathered basalt. A water absorption band at 2.9 micrometers is due to small amounts of clay formed by weathering. A doublet at 3.4 micrometers due to C-H stretching vibraations is the result of small amounts of organic matter.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

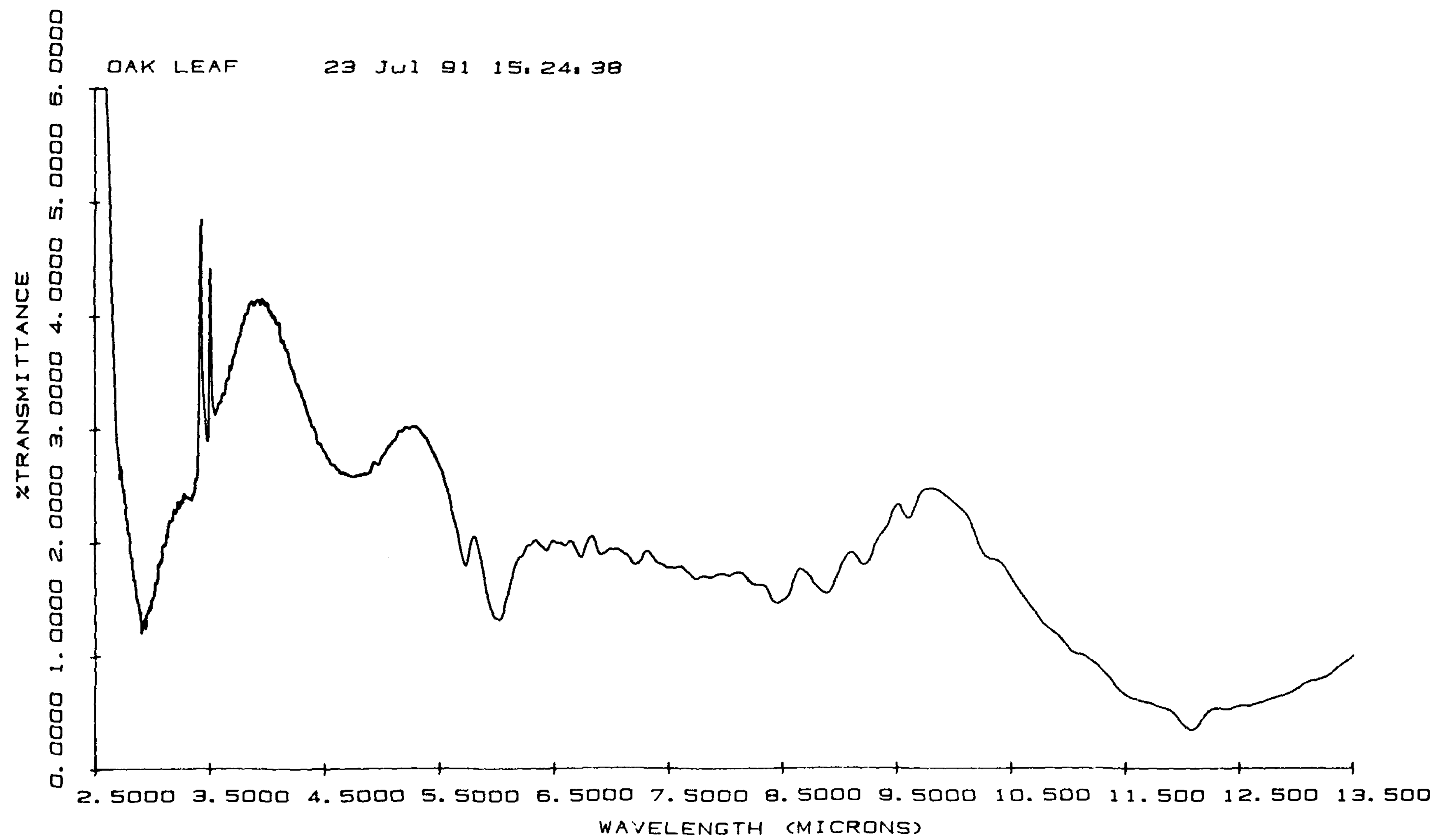

COTTON. S1
22 May 90 15: 11: 04
% REFLECTANCE
0. 0000
7. 0000
14. 000
21. 000
28. 000
35. 000
42. 000
2. 5000
3. 5000
4. 5000
5. 5000
6. 5000
7. 5000
8. 5000
9. 5000
10. 500
11. 500
12. 500
13. 500
WAVELENGTH (MICRONS)

Sample: Cotton fiber

Sample description: Sample was cut from general purpose undyed cotton gauze.

Comments: In this spectrum molecular vibration bands are virtually all expressed as troughs. This can be seen in the strong O-H stretching vibration bands at 2.9 and 3.0 micrometers as well as strong C-H stretching vibration bands near 3.4 micrometers. The exact nature of a strong triplet centered at 4.7 micrometers is uncertain but is likely a hydrocarbon feature of some sort. The strong band near 6.1 micrometers is probably due to C-O stretching vibrations. A strong absorption near 11.2 micrometers is likely related to vibrations involving C-O stretching.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.



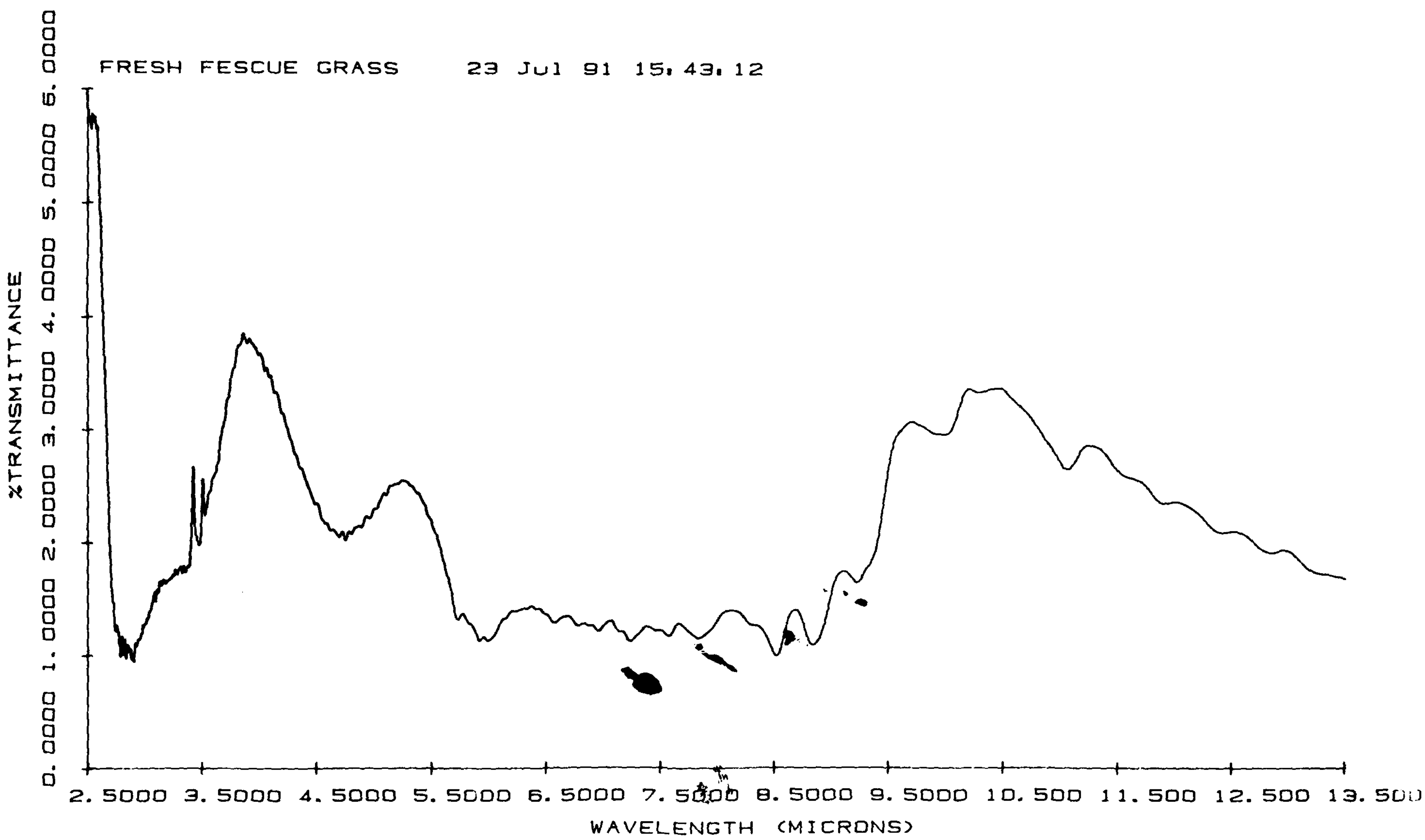
OAK LEAF 23 Jul 91 15:24:38
%TRANSMITTANCE
0.0000 1.0000 2.0000 3.0000 4.0000 5.0000 6.0000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Oak leaf

Sample data: Sample was collected 23 Jul 91 at U S Geological Survey in Reston, VA. Spectral measurement was made on upper surface of the leaf within 30 minutes of collection.

Comments: The thermal infrared reflectance and spectral contrast of leaf and vegetation matter is generally much lower than that of rocks, soils and minerals. If measured on the same scale of reflectance as the latter materials, vegetation often appears as a dark gray body. Thermal infrared spectral features of leaves generally originate from surface reflectance associated with hydrocarbon bands of the waxy outer layer of the leaf (cuticle) plus strong absorption bands due to water. In this spectrum only two features are identified with certainty. These are the absorption band at 2.9 micrometers due to O-H in water and the cuticle layer, and the doublet feature centered about 3.4 micrometers, due to hydrocarbon C-H stretching. The remainder of the spectrum is made up of many closely spaced, poorly resolved features which have not been identified, but are most likely associated with the cuticle layer.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

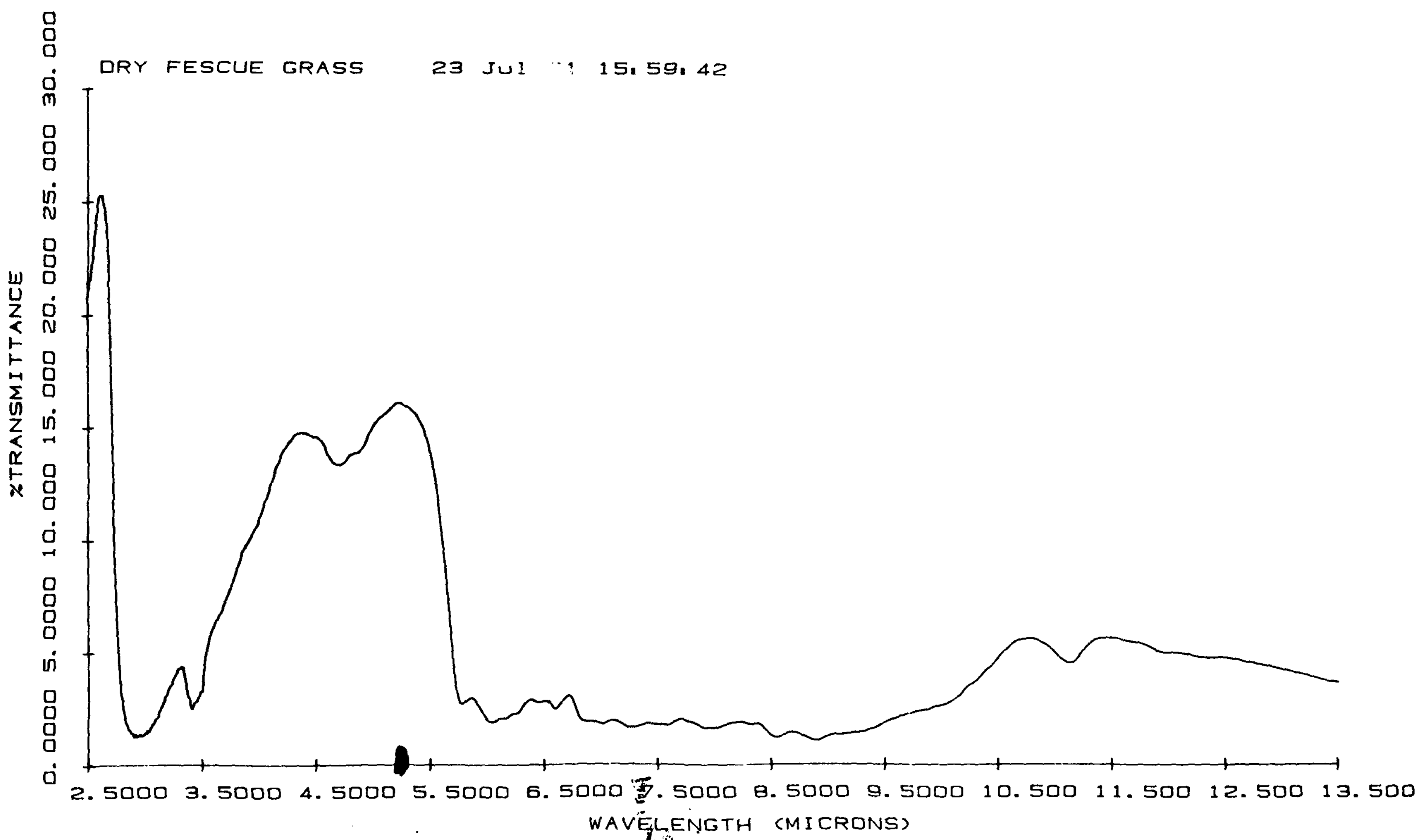

FRESH FESCUE GRASS 23 Jul 91 15:43:12
%TRANSMITTANCE
0.0000 1.0000 2.0000 3.0000 4.0000 5.0000 6.0000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Green fescue grass

Sample data: Sample was collected 23 Jul 91 from lawn of U S Geological Survey in Reston, VA. Spectrum was measured on fresh grass clippings which had been arranged into a loose flat mat.

Comments: The thermal infrared reflectance and spectral contrast of leaf and vegetation matter is generally much lower than that of rocks, soils and minerals. If measured on the same scale of reflectance as the latter materials, vegetation often appears as a dark gray body. Thermal infrared spectral features of leaves generally originate from surface reflectance associated with hydrocarbon bands of the waxy outer layer of the leaf (cuticle) plus strong absorption bands due to water. In the spectrum only two features are identified with certainty. These are the strong water absorption band at 2.9 micrometers and the doublet feature centered about 3.4 micrometers, which is due to hydrocarbon C-H stretching. The remainder of the many closely spaced and poorly resolved features are likely associated with the cuticle, but have not been identified.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.



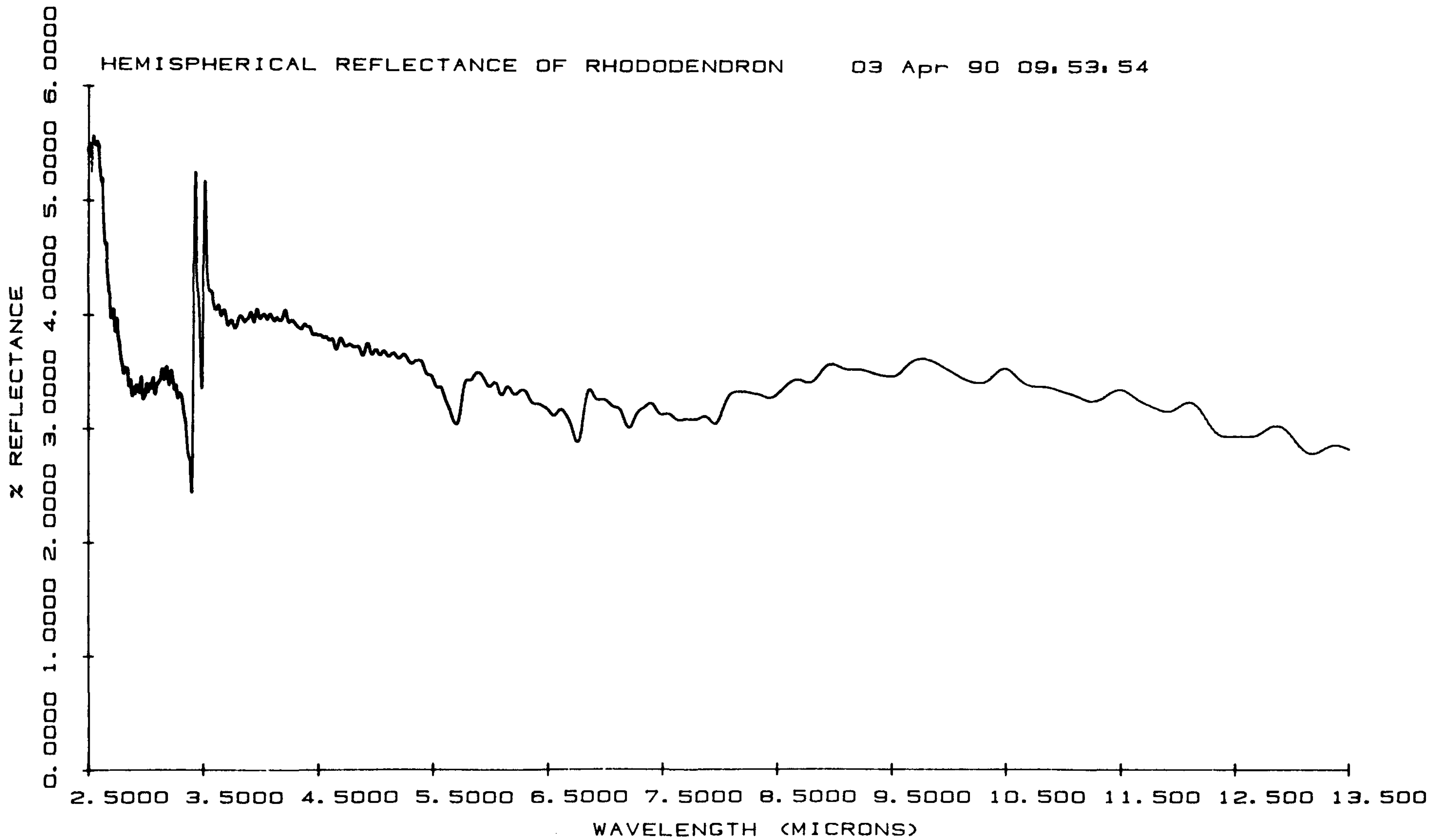
DRY FESCUE GRASS 23 Jul 15.59.42
%TRANSMITTANCE
0.0000 5.0000 10.000 15.000 20.000 25.000 30.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Dry fescue grass

Sample data: Sample was collected 23 Jul 91 from lawn of U S Geological Survey in Reston, VA. Spectrum was measured on dry grass clippings which had been arranged into a loose flat mat.

Comments: The thermal infrared reflectance and spectral contrast of leaf and vegetation matter is generally much lower than that of rocks, soils and minerals. If measured on the same scale of reflectance as the latter materials, vegetation often appears as a dark gray body. Thermal infrared spectral features of leaves generally originate from surface reflectance associated with hydrocarbon bands of the waxy outer layer of the leaf (cuticle) plus strong absorption bands due to water. The reflectance of this sample of dry grass is higher throughout the spectrum than that of fresh grass due to decreased absorption by water. In this spectrum only two features are identified with certainty. These are the absorption band at 2.9 micrometers due to O-H in water and the cuticle layer, and the doublet feature centered about 3.4 micrometers, due to hydrocarbon C-H stretching. The spectrum is similar to that of cotton fiber, which is to be expected because both cotton and the dry grass are almost pure cellulose.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.

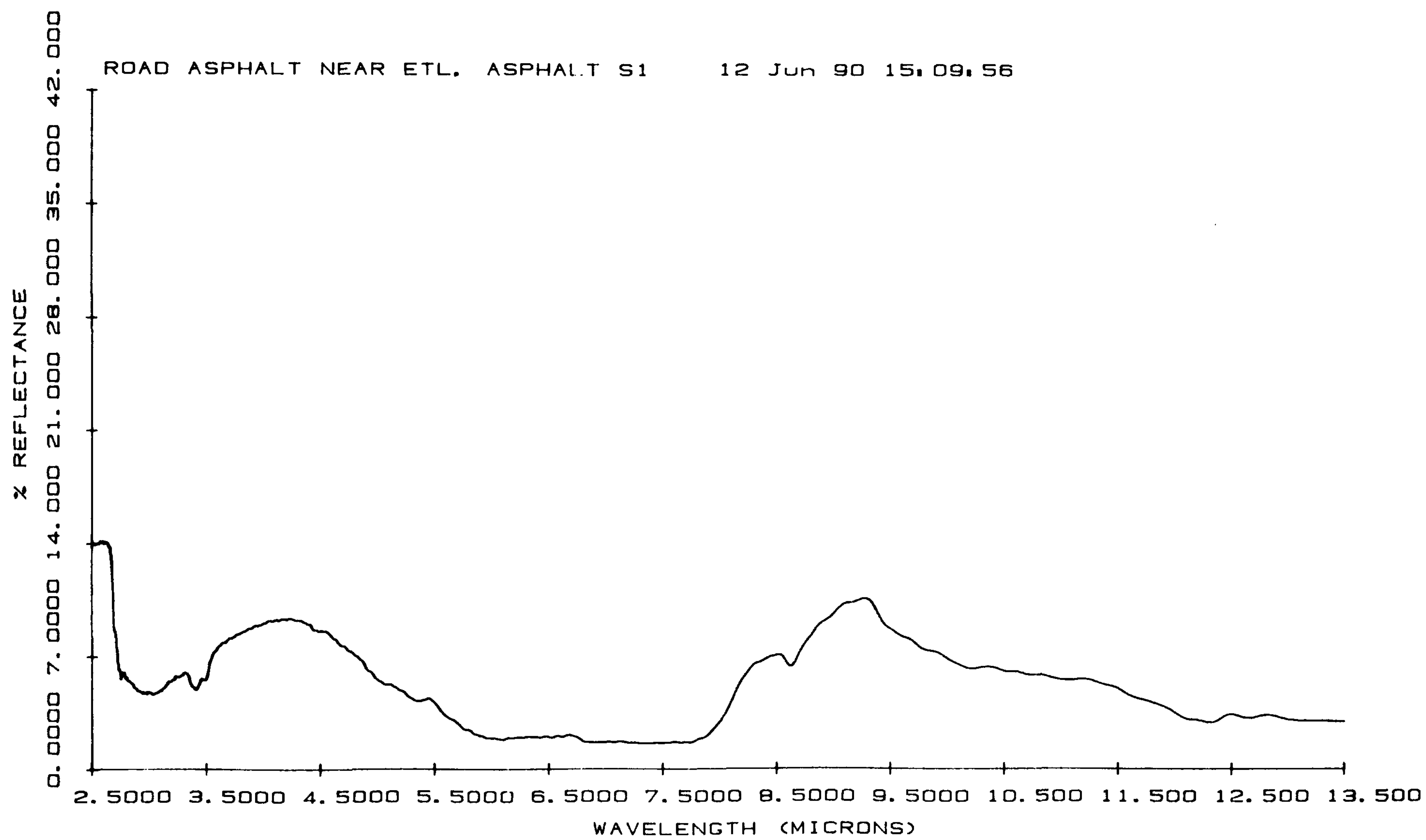

HEMISPHERICAL REFLECTANCE OF RHODODENDRON 03 Apr 90 09:53:54
% REFLECTANCE
0.0000 1.0000 2.0000 3.0000 4.0000 5.0000 6.0000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (MICRONS)

Sample: Rhododendron leaf

Sample data: Sample was collected 3 Apr 90 at U S Geological Survey in Reston, VA. Spectral measurement was made on upper surface of the leaf within 30 minutes of collection.

Comments: The thermal infrared reflectance and spectral contrast of leaf and vegetation matter is generally much lower than that of rocks, soils and minerals. If measured on the same scale of reflectance as the latter materials, vegetation often appears as a dark gray body. Thermal infrared spectral features of leaves generally originate from surface reflectance associated with hydrocarbon bands of the waxy outer layer of the leaf (cuticle) plus strong absorption bands due to water. In this spectrum only two features are identified with certainty. These are the absorption band at 2.9 micrometers due to O-H in water and the cuticle layer, and the doublet feature centered about 3.4 micrometers, due to hydrocarbon C-H stretching. The remainder of the spectrum is made up of many closely spaced, poorly resolved features which have not been identified, but are most likely associated with the cuticle layer.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.


ROAD ASPHALT NEAR ETL. ASPHALT S1 12 Jun 90 15:09:56
% REFLECTANCE
0.0000
7.0000
14.000
21.000
28.000
35.000
42.000
2.5000
3.5000
4.5000
5.5000
6.5000
7.5000
8.5000
9.5000
10.500
11.500
12.500
13.500
WAVELENGTH (MICRONS)

Sample: Road Asphalt

Sample data: Sample is a small weathered hand-sample collected from access road to Engineer Topographic Laboratories, Ft. Belvoir, VA by J. W. Eastes.

Comments: The spectrum is dominated by silicate features in the 8 to 13 micrometer region. Doublet features centered at 12.5 and 8.6 micrometers indicate a considerable amount of quartz. However the feature at 8.6 micrometers is distorted by the presence of weathering products and other undetermined silicate species. Hydrocarbon bands at 3.5 micrometers are due to organic components of the asphalt. A sharp hydroxyl O-H band occurs at 2.7 micrometers and a broader water band occurs at 2.9 micrometers. The hydroxyl band may be due in part to a thin film of clay on the surfaces of some grains, which also distorts the quartz doublet.

Acquisition of spectrum: Spectrum was recorded at 4 cm(-1) resolution using a Nicolet 5DXB FTIR spectrometer and gold coated integrating sphere with cooled MCT detector.